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ROORKEE

HYDRAULIC EXPERIMENTS.

BY

CAPT. ALLAN CUNNINGHAM, R.E.,

HONY. FELLOW OF KING'S COLLEGE, LONDON.

VOL. III.—PLATES.

ROORKEE:

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1880.

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EXPERIMENTS DRAWING STAFF.

Draughtsman, ... Capt. Allan Cunningham, R.E.

Senior Check-Draughtsman, Sergt. W. Porters, R.E.

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INTRODUCTION TO PLATES.

1. Description of Plates.—The Plates consist chiefly of—

1°. Plans, Longitudinal, and Cross-Sections of the Canal, &c.
2°. Drawings of Instruments, Sketches of Experiments, Geometrical Diagrams.
3°. Vertical and Transverse Velocity-Curves, Transverse Silt-Curves.
4°. Grouped Curves showing relations of various quantities.

Detailed Descriptions of the Plates are given in the Text. Very free use has been made of "graphic representations", (Nos. 3°, 4° above,) as appealing readily to the eye. A reference to such Diagrams will frequently *save a laborious study* of the printed Tables. Some general explanations of these are given below.

2. Velocity and Silt-Curves.—(Plates XII-XVIII, XXVI-XLI, L).

In these the ordinates show Velocities and Quantities of Silt at the points on the Base-line (Vertical or Transversal) from which they start. The tips of the ordinates are joined by straight lines, thus forming a rough VELOCITY-CURVE or SILT-CURVE as the case may be, free from any bias of the draughtsman's hand. Except in "Grouped Curves", (*e. g.*, Plates XXX., L., for which see next para.,) computed ordinates and curves are shown in dotted lines; measured ordinates and observation-curves in clear lines.

(i). *Mean Lines.*—A Line drawn across the ordinates parallel to the Base-Line at a distance from it equal to the "mean ordinate" serves to indicate the value of the latter (by its distance from the Base-Line), *i.e.*, of the "Mean-Velocity", "Mean Silt", &c.

(ii). *Cross-Sections.*—For all Non-Central Vertical Velocity-Curves the position of Vertical is shown on a Cross-Section complete or partial as required (Plates XVI.-XVIII.) A complete Cross-Section showing the position of all Float-Courses is given also at foot of every Plate of Transverse Velocity- or Silt-Curves (Plates XXVI.-XLI., L.)

(iii). *Instruments.*—The vertical lines at the tips of the Rod-velocity (u) lines in the Vertical Velocity-Curves, (Plates XII.-XVIII.), and those in the Cross-Sections which accompany them; also those at intervals in the Cross-Sections below the Mid-depth-, Bed-, and Mean-Velocity Curves (Plates XXIX.-XLI.) may be looked on as pictorial representations of some of the Instruments employed, viz.,

Plates XII.-XVIII., and XXXI.-XLI., Mean Velocity-Rods.

Pl. XXIX., Double-Floats; Pl. XXX., Double-Floats and Mean Velocy.-Rods.

(iv). *Notation for h*, H, R.—For each Transverse Velocity- and Silt-Curve, (Plates XXVI.-XXIX., XXXI.-XLI., L.), several of the "hydraulic elements", *viz.*,

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the Gauge-Reading (h), Central Depth (H), and Hydraulic Mean Depth (R) are plotted upwards from the Base-Transversal upon a single vertical ordinate (placed to one side of the Curve), their several lengths being shown by a horizontal scratch at the top, so that they can be compared by inspection.

3. Grouped Curves.—(Pl. VIII., IX., XXI.-XXIII., XXX., XLII.-L).

To exhibit the relations between several quantities (*e. g.*, Velocities at various points, Surface-Falls, Surface-Slopes, &c.,) at once, corresponding values of these quantities are plotted together *upon a common ordinate*, measured from a common Base-Line, with any chosen quantity as abscissa.

The successive plotted points of any one kind are joined usually by straight lines, sometimes by curved lines (when curving helps to clearness), thus forming a rough Curve of the quantity in question, free from bias of the draughtsman's hand; and the whole forming a Group of related Curves. The Curves are drawn for clearness' sake in different styles, *e. g.*, clear, dotted, chain-dotted, and long dashes.

4. Breaks in Curves and Ordinates.—These arise in the Grouped Curves from various causes :—

1°. *Missing Data.* The Curves are drawn *continuous* across the ordinates *only through actual plotted points;* thus, if on any ordinate the plotted point be missing (from want of data), the Curve is *broken off at the crossing therewith.*

2°. *Admixture of Sites.* When the data for several Sites are plotted on one Plate, the whole group of Curves of one Site sometimes cross an ordinate peculiar to another Site. In this case either the whole group of Curves is slightly *broken off at the crossing* (as in Plates VIII., XLVIII.), or the ordinate itself is *broken at each Curve* (as in Plates XLIV., XLVII.)

3°. *Interlacing and Acute Intersections.* When the close interlacing of the Curves or their acute intersections with the ordinates would be likely to cause confusion, either the ordinates are *broken at the crossing* with the Curve (this is the common case), or the Curves are *broken between the ordinates* (as in Plates VIII., XXI., XLV.) In the latter case arrows are sometimes added (Plates VIII., XLV.) to guide the eye when the gap is a long one.

5. Scales.—The same scales have been used for quantities of same kind (as far as the limits of the paper would permit) throughout the Plates. The scales used on each Plate can be recognised from the references given on each.

6. Symbols.—The same symbols are used as in the Tables; for explanation, *see* Art. 8, 9 of Introduction to Tables. Explanations of special symbols used in certain Plates are given either on the Plates themselves or in the Text.

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7. Wind.—The state of the Wind is shown by an arrow, drawn *towards the wind's eye*, and of length showing the velocity on a given scale, (thus showing both direction and force).

8. Preparation of Plates.—The Plates have been prepared with great care. Every Plate was prepared in MS. by the Superintendent himself, and *checked throughout* by one* of the Computer Staff.

The "transfer-paper" and "first proof" were always checked—in all details (except actual replotting) by one of the Computer Staff, (in addition to the usual checking by the Press Staff), and in all but the figure detail (and actual replotting) by the Superintendent himself. Every correction was checked on each revision by one of the Computer Staff and by the Superintendent himself.

It was found useless to carry the checking to the extent of *actual replotting*, as the shrinkage of the paper in the process of lithography as carried out in India is so great and so irregular, that the final Result cannot be expected to be to scale (according to the scale named thereon). The diagrams should, however, be correct in the relative disposition of their parts.

9. Errata.—With every care it has, however, been impossible to avoid mistakes altogether. A few Errata were discovered while the Work was passing through the Press. The worst of these have been corrected by hand† so as to save trouble to the reader: these therefore no longer appear as Errata. A List of all the rest as far as known‡ is published below. The reader is requested to correct these with the pen.

* Nearly all by the Senior Computer and Checker, (Sergt. W. Porters, R.E.)

† Some of the corrections are of course a little rough in appearance.

‡ The author will be glad to receive a note of any further Errata discovered. Address to the Thomason C. E. College, N. W. P., India.

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ERRATA.

[The Reader is requested to correct these with the pen].

Pl. II, 2. Height of Bed above Lower Datum on 13-11-'78,
At 73'·75 Right of Centre ; *for* 2'·46, *read* 2'·48.

Pl. XX. References for Fig. 3 (at Head of Plate) ; *for* $bM = \frac{1}{4}H$, *read* $bm = \frac{1}{4}H$.

Pl. XXIV, 11. In the Elevation the depth of the Pan is incorrectly drawn and figured as 12". This should be 9" (both in drawing, and figuring).

Pl. XXVI, Ser. 56. *For* $U_o = 3{\cdot}78$, *read* $U_o = 3{\cdot}79$.

Pl. XXX, 1. Ser. 111. *For* $H = 9'{\cdot}87$, *read* $H = 8'{\cdot}97$.

Pl. XXXVI, Ser. 176. On ordinate at 65' Right of Centre, *for* 1·56, *read* 1·55.

Pl. XXXVI, Ser. 179. On ordinate at 40' Right of Centre, *for* 1·46, *read* 1·45.

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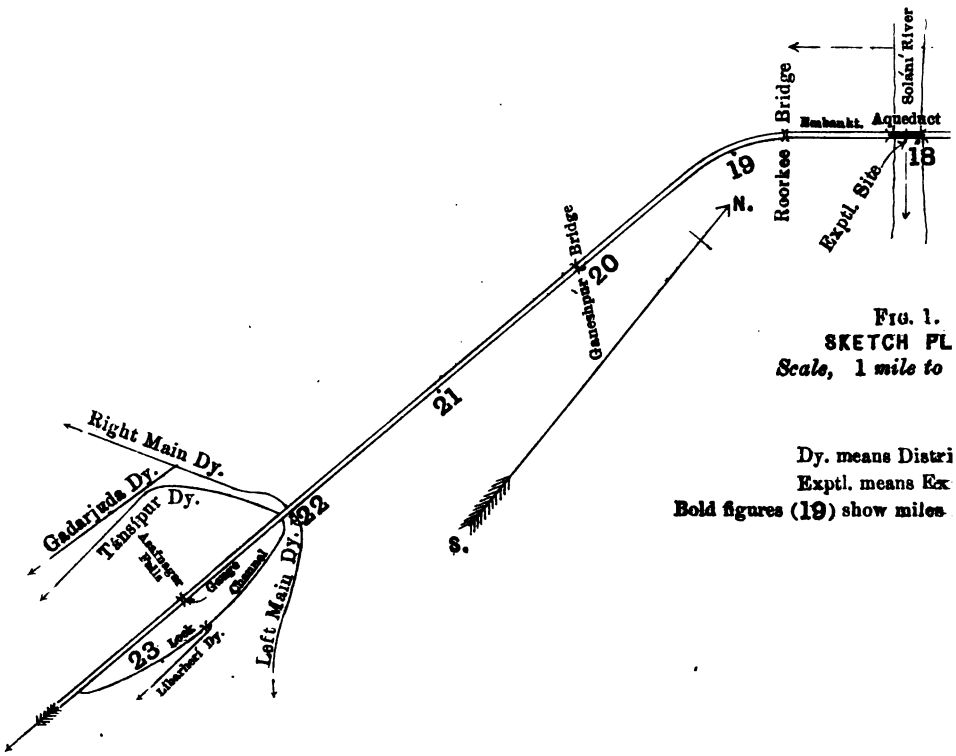
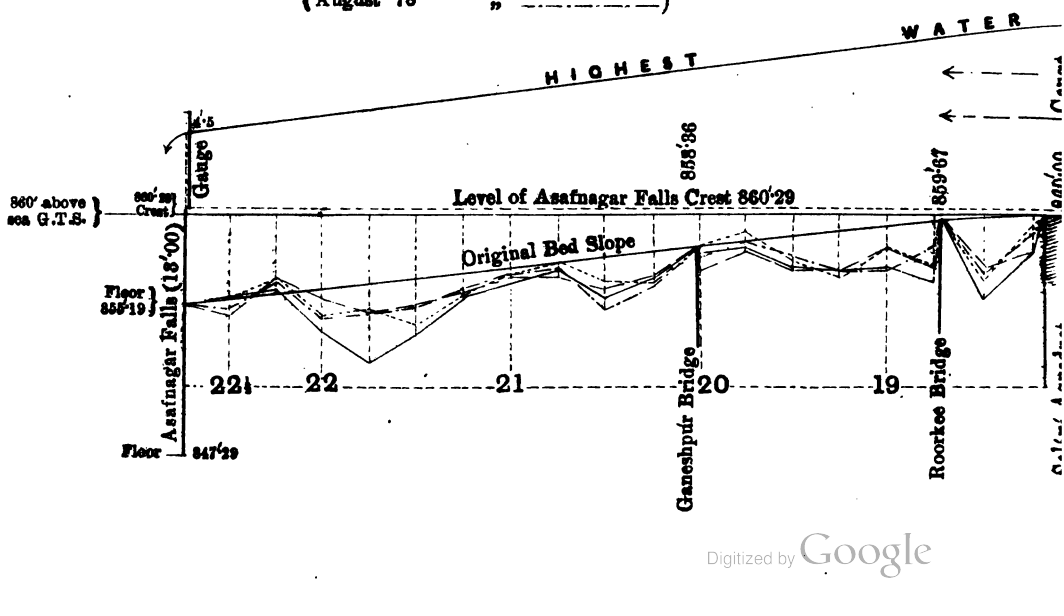


FIG. 1.
SKETCH PL
Scale, 1 *mile to*

Dy. means Distri
Exptl. means Ex
Bold figures (19) show miles

LONGITUD
Horizontal Scale, 1 *mile to an inc*

Centre Line of Bed	August '75	thus	.....
	August '76	„	— — —
	October '77	„	———
	August '78	„	—·—·—



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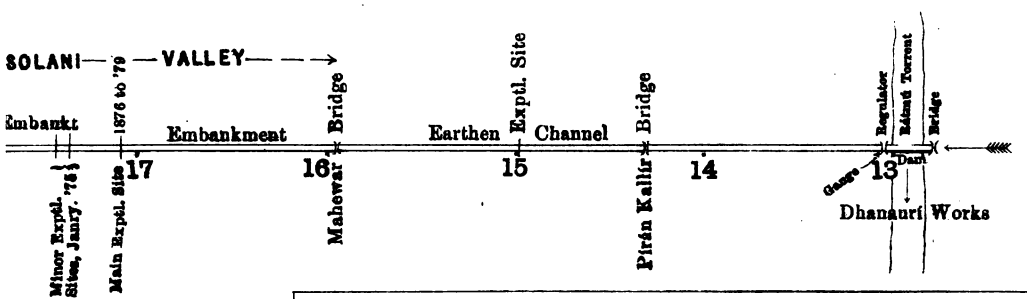
CANAL—ROORKEE REACH.



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on Head of the Canal.

FIG. 3.

SOLANI RIGHT AQUEDUCT SITE

ENLARGED CROSS-SECTION OF BANKS

Scale, 10 *feet to an inch.*

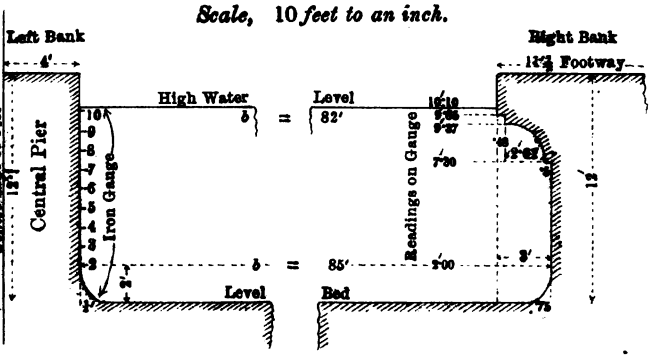
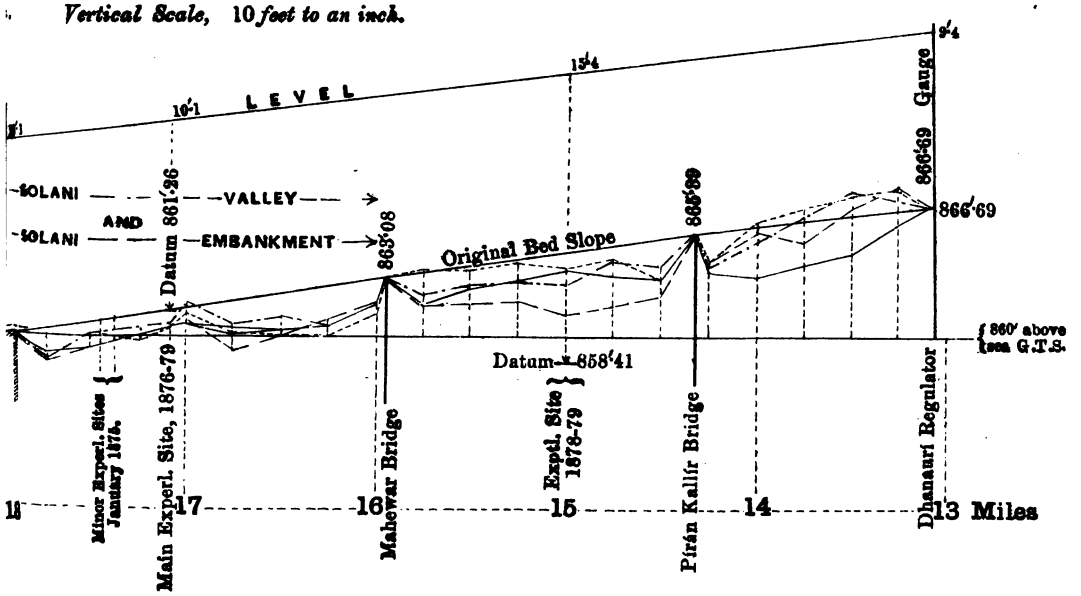


FIG. 2.

NAL SECTION

Vertical Scale, 10 *feet to an inch.*



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GANGES CANAL—ROORKEE REACH.

Scale for all Cross-Sections, 25 feet to an inch.

FIG. 1.

FIFTEENTH MILE SITE

AVERAGE CROSS-SECTIONS

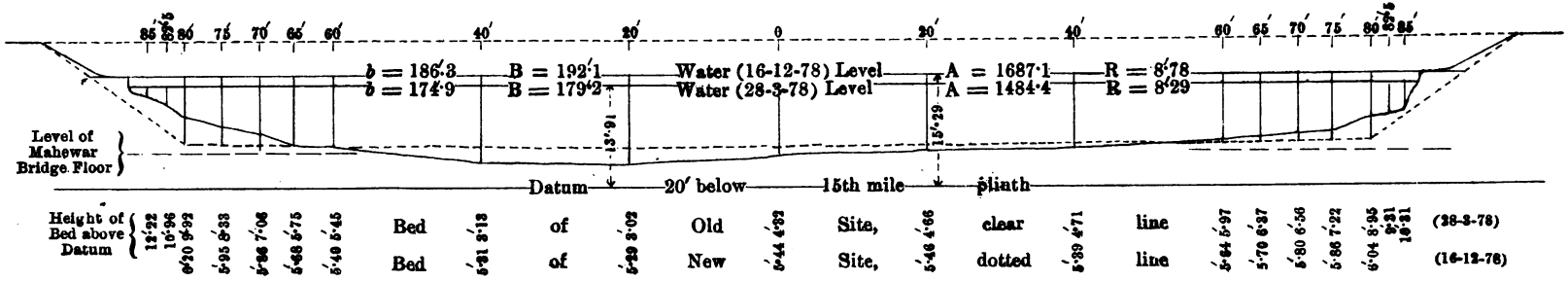

FIG. 2.

SOLANI EMBANKMENT MAIN SITE

AVERAGE CROSS-SECTIONS

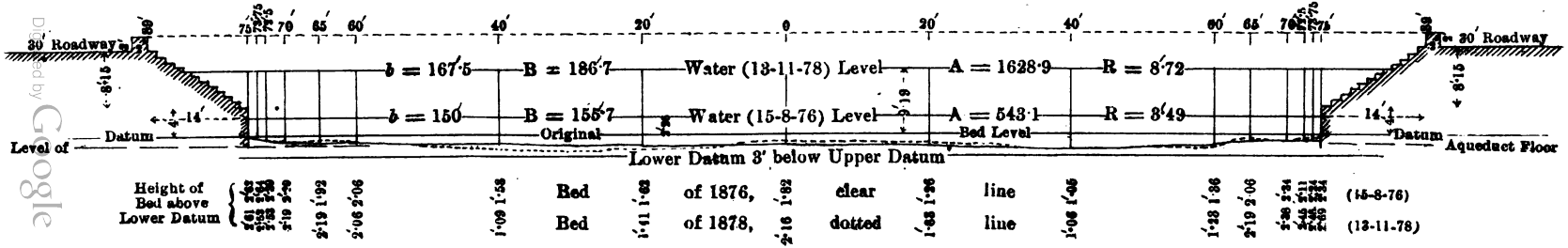
30′ Roadway
80 75 70 65 60 40 20 0 20 40 60 65 70 75 80
30′ Roadway
8·15
b = 167·5 B = 186·7 Water (13-11-78) Level A = 1628·9 R = 8·72
b = 150 B = 155·7 Water (15-8-76) Level A = 543·1 R = 8·49
3·19
14′
Datum
Original Bed Level
Level of
Lower Datum 3′ below Upper Datum
Aqueduct Floor
Height of Bed above Lower Datum
2·19 1·93 2·06 2·06 1·09 1·58
Bed 1·11 1·62 of 1876, 2·16 1·62 clear 1·83 1·96 line 1·06 1·06
Bed of 1878, dotted line
1·23 1·86 2·19 2·06 (15-8-76)
(13-11-78)

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FIG. 3.

SOLANI AQUEDUCT

PLAN OF AQUEDUCT AND APPROACHES

Scale, 250 feet to an inch.

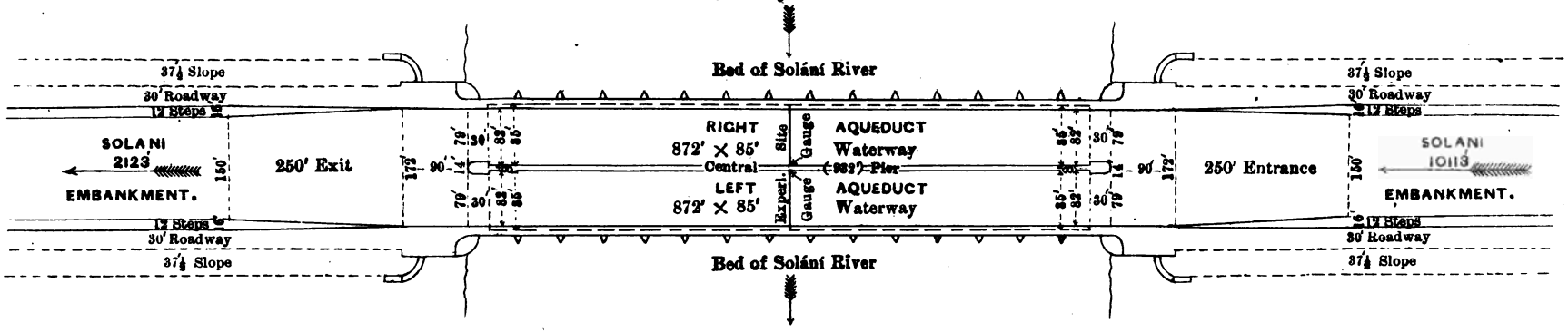
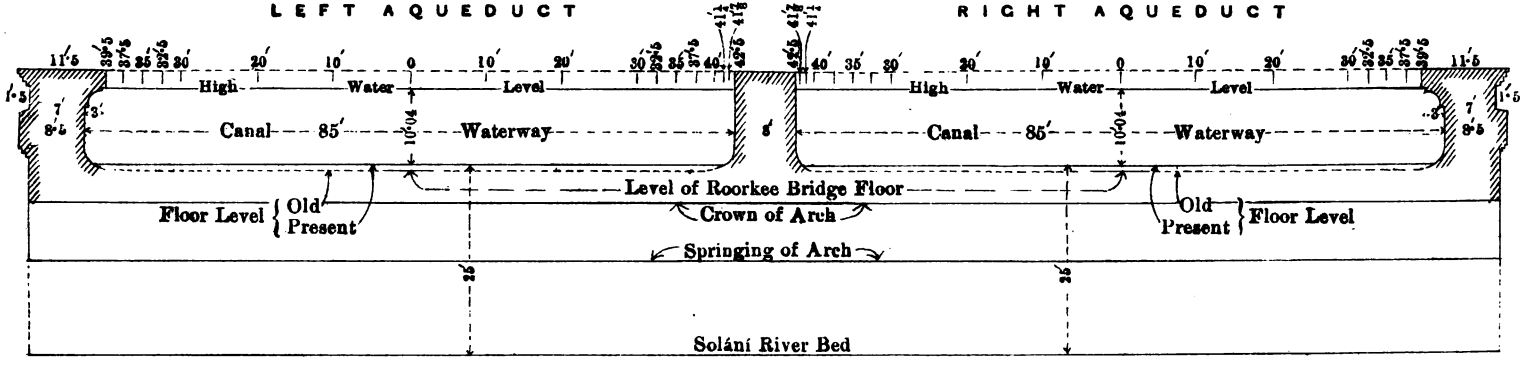


FIG. 4.

C R O S S — S E C T I O N



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GANGES CANAL—BELRA, JAOLI, A

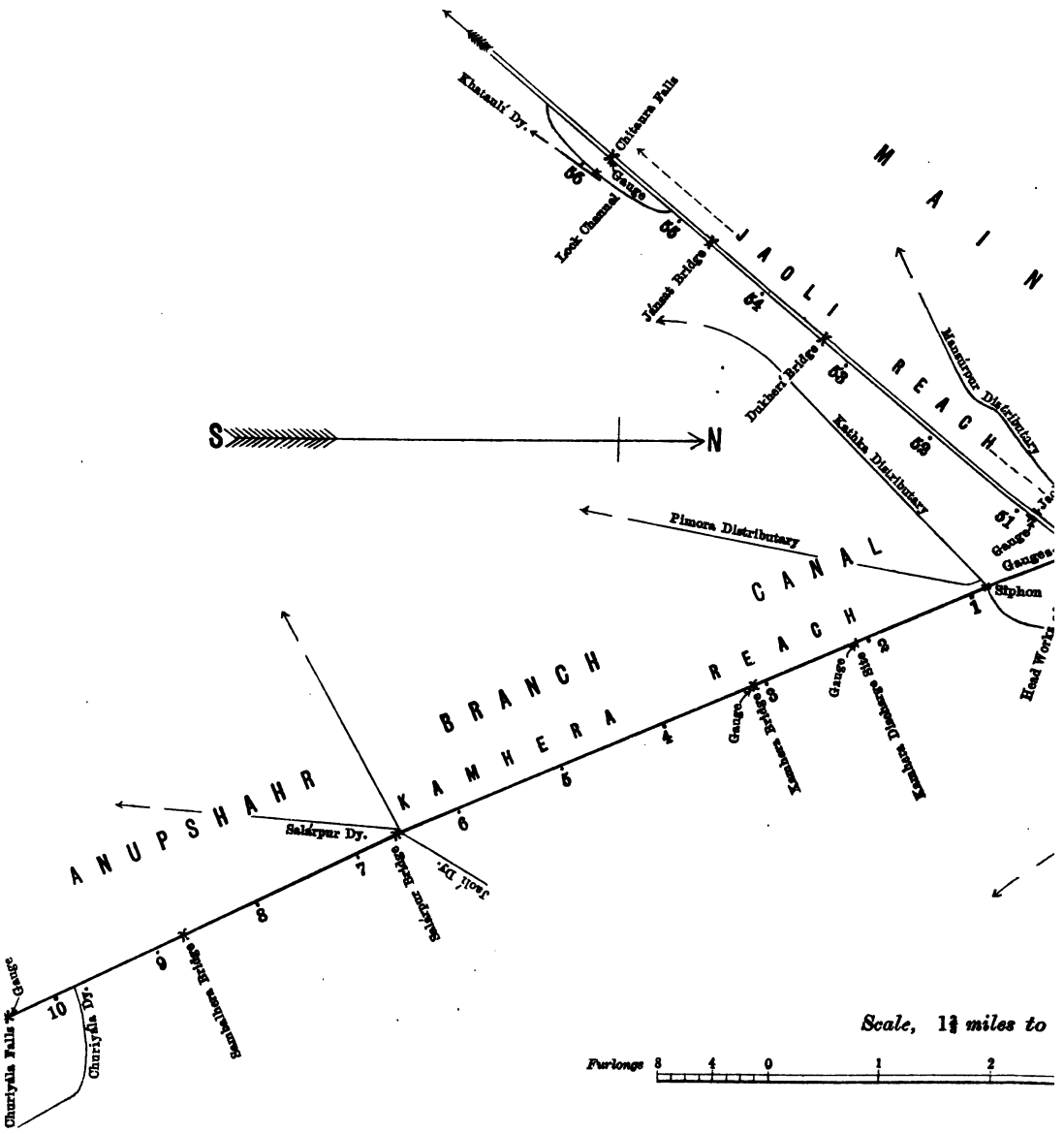
GENERAL SKET(

Abbreviations

Disch. Site means Dischs

Dy. means Distribu

Bold figures as (45), (7) show mileage from Head-Worl



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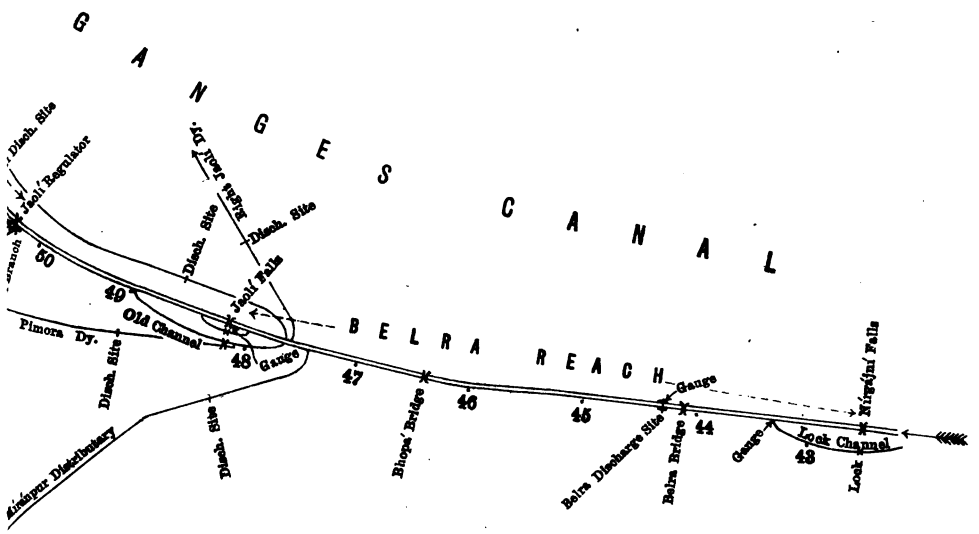
ND KAMHERA REACHES.

PLATE III.

H PLAN

ge Site.
ary.
s of Main Canal or of Branch Canal.



inch.

3 4 5 *Miles*

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GANGES CANAL—BELRA REACH.

PLATE IV.

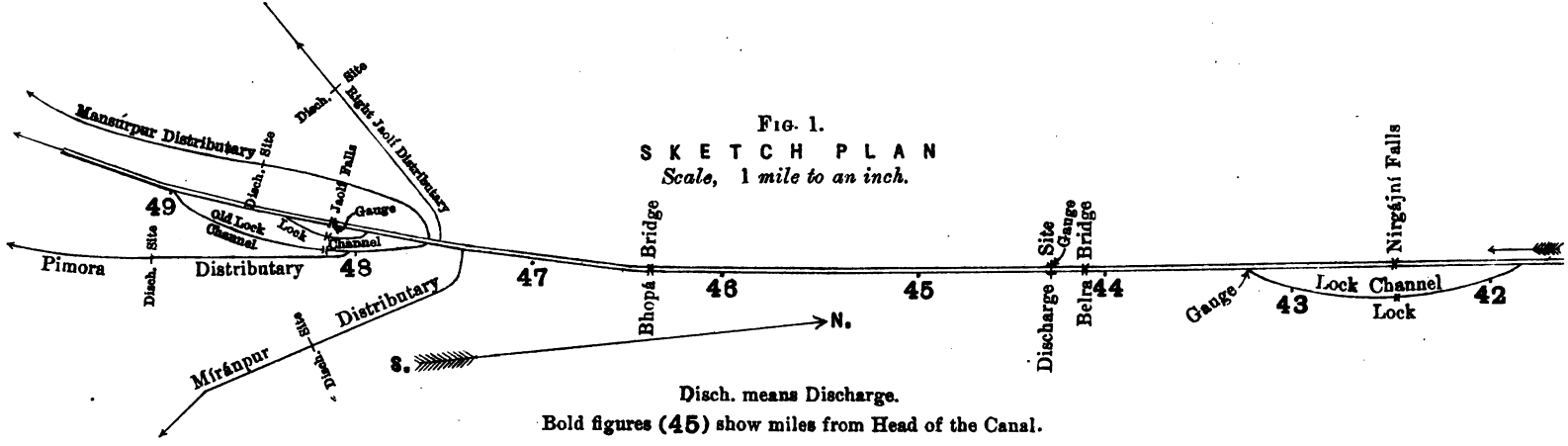

FIG. 1.

SKETCH PLAN

Scale, 1 *mile to an inch.*

Disch. means Discharge.

Bold figures **(45)** show miles from Head of the Canal.

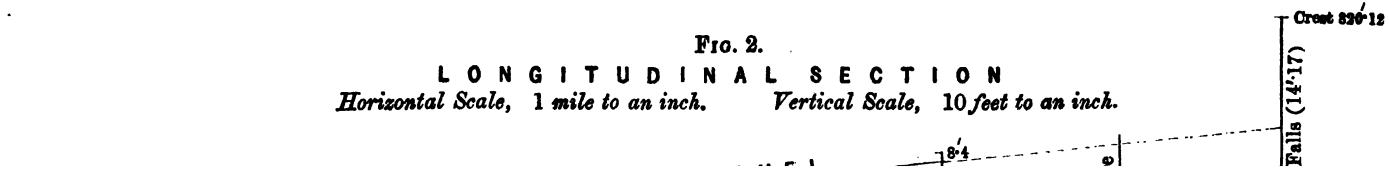

FIG. 2.

LONGITUDINAL SECTION

Horizontal Scale, 1 *mile to an inch.* *Vertical Scale,* 10 *feet to an inch.*

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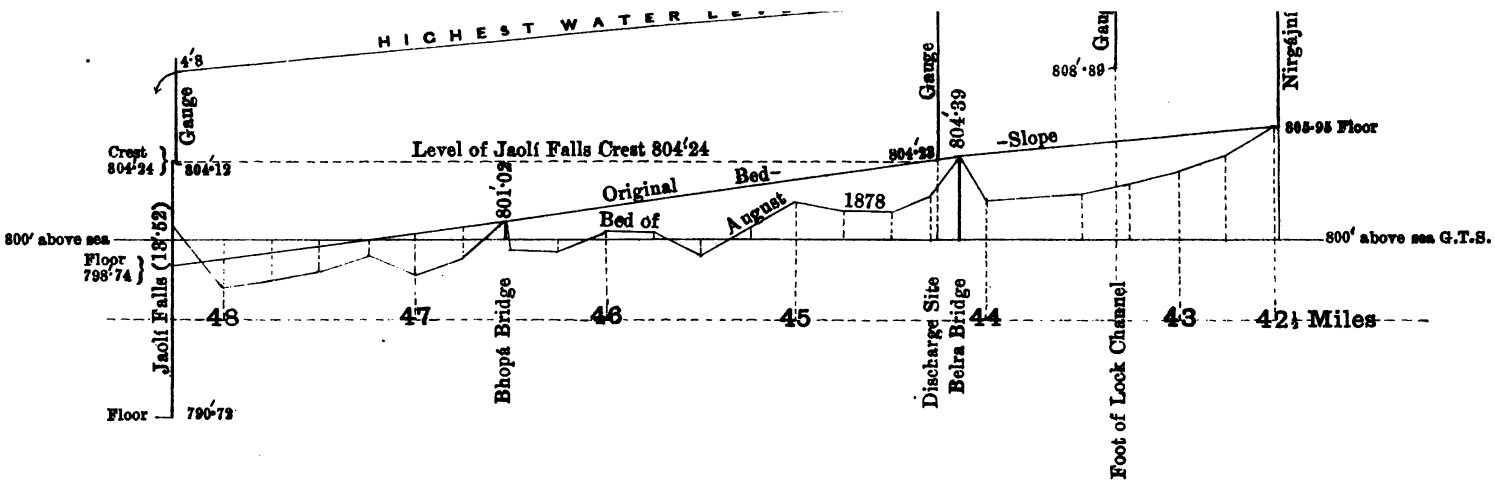
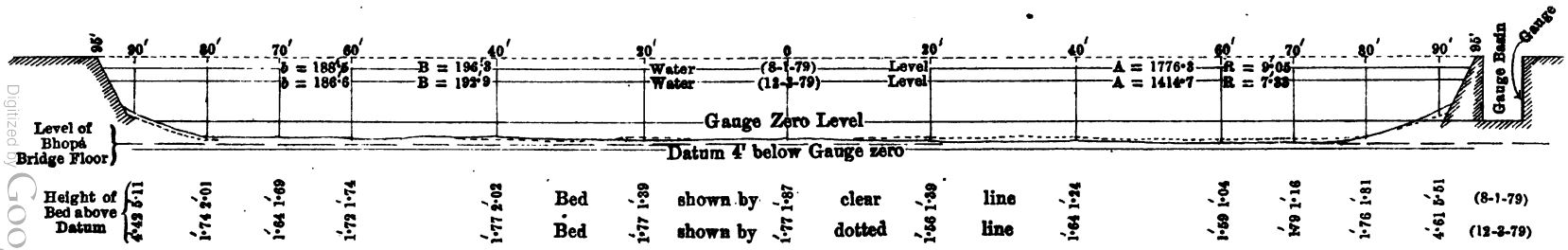


Fig. 3.

AVERAGE CROSS-SECTIONS

Scale, 25 feet to an inch.



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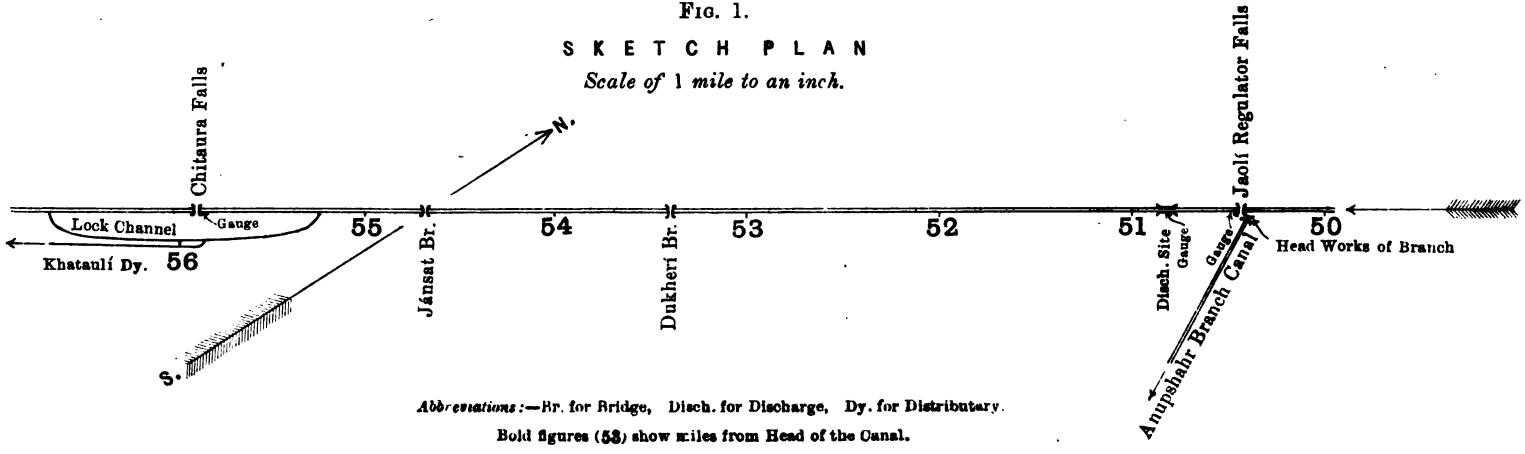
GANGES CANAL—JAOLI REACH.

FIG. 1.

SKETCH PLAN

Scale of 1 *mile to an inch.*



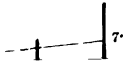
Abbreviations:—Br. for Bridge, Disch. for Discharge, Dy. for Distributary.

Bold figures (**53**) show miles from Head of the Canal.

FIG. 2.

LONGITUDINAL SECTION

Horizontal Scale, 1 *mile to an inch.* *Vertical Scale,* 10 *feet to an inch.*



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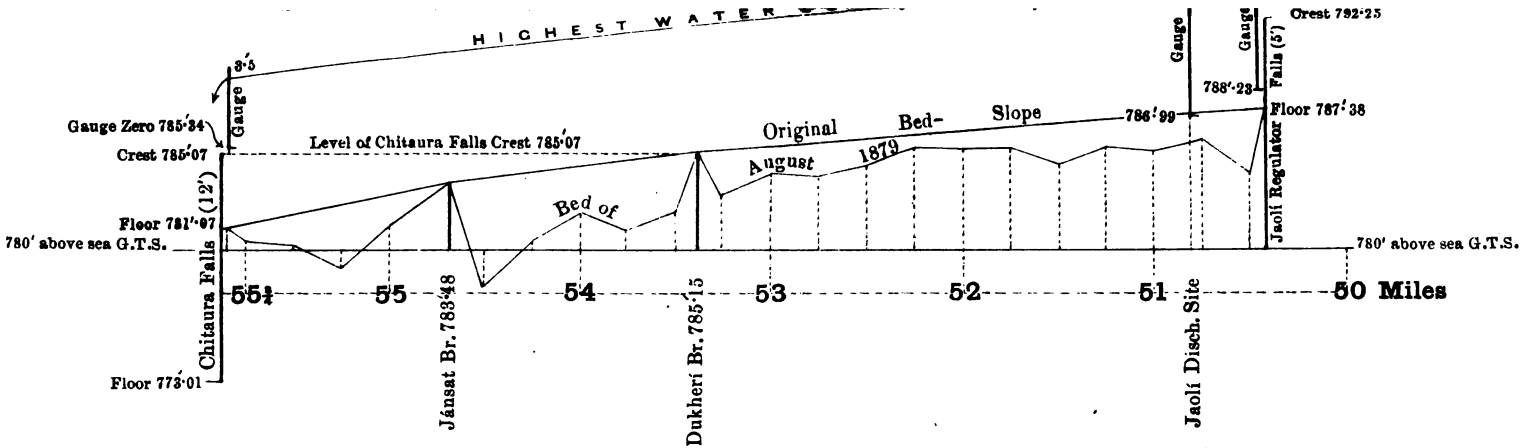
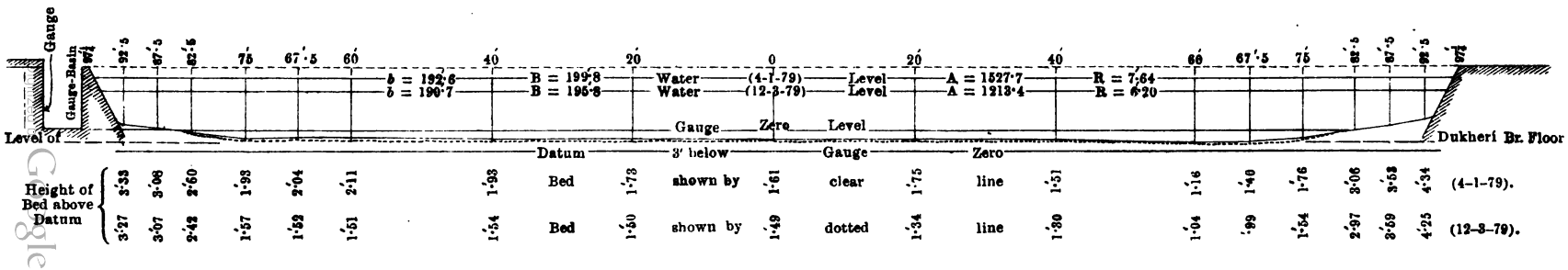


FIG. 3.

AVERAGE CROSS-SECTIONS

Scale 25 feet to an inch.



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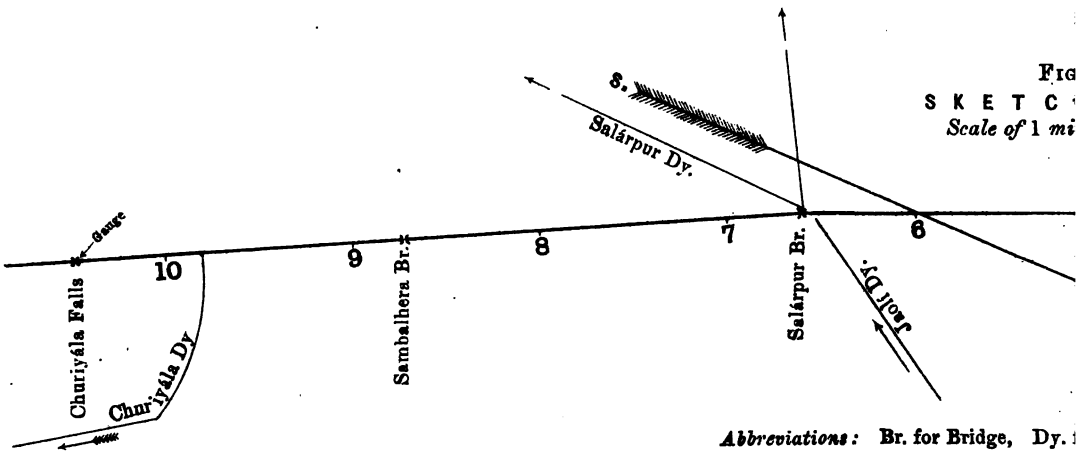
ANUPSHAHR BRANCH CA

FIG
SKETC
Scale of 1 *mi*



Abbreviations: Br. for Bridge, Dy.
Bold figures (7) show miles from

FIG
LONGITUDIN
Horizontal Scale, 1 *mile to an inch.*

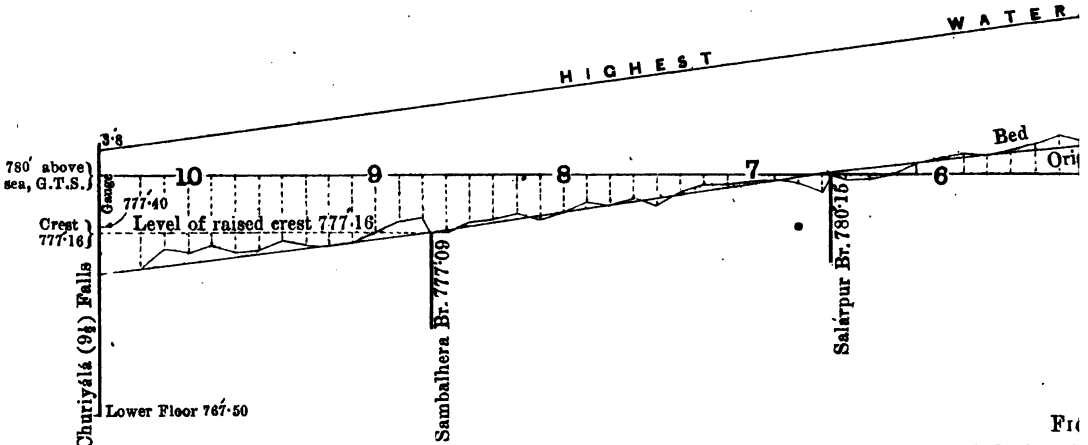
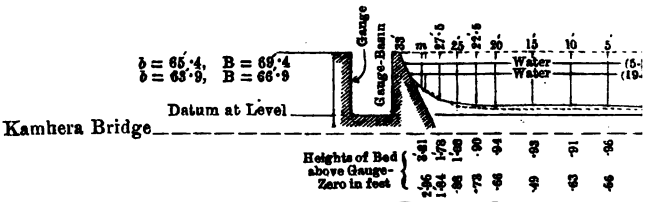


FIG
AVERAGE CRO
Scale of 25 *fe*



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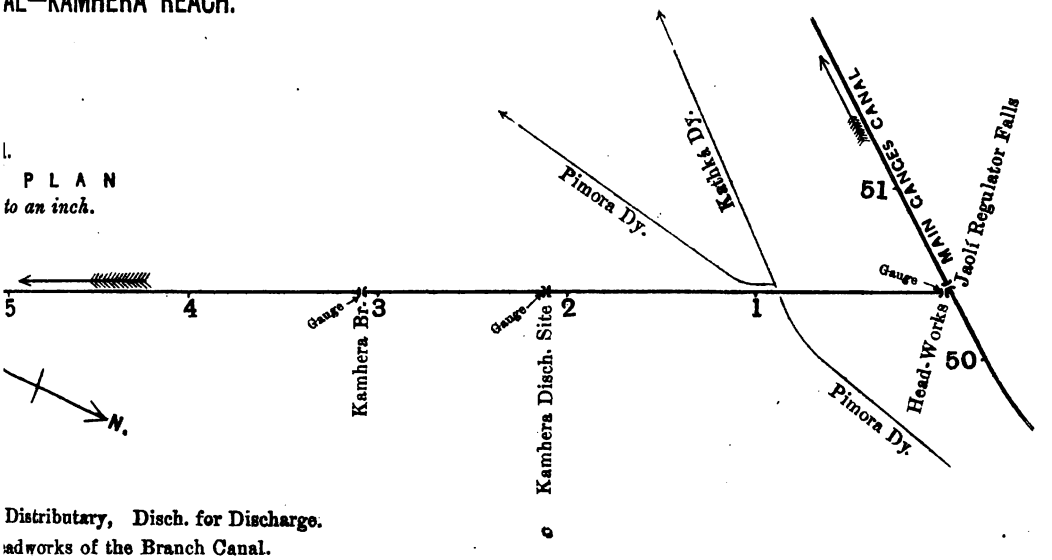
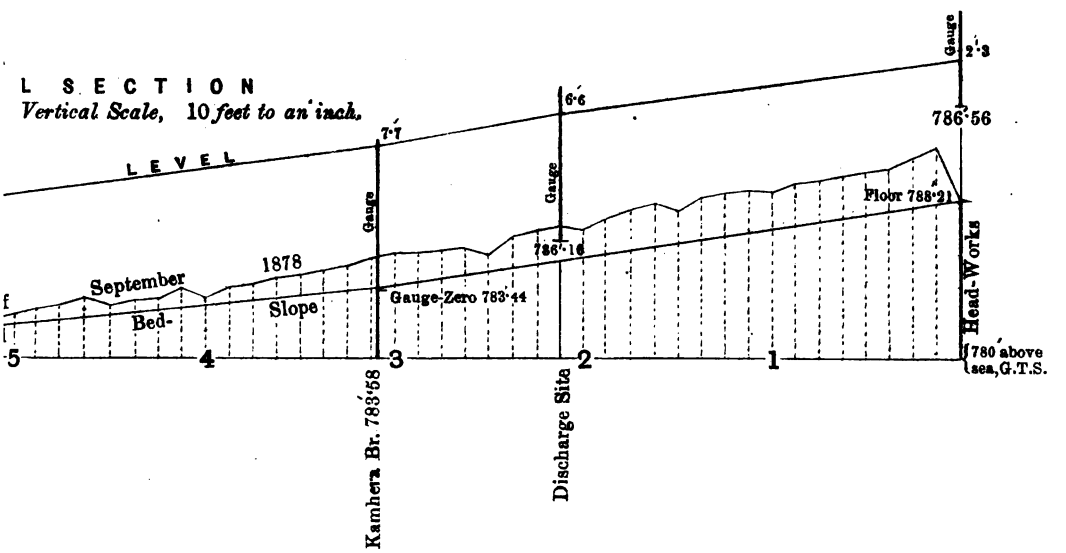
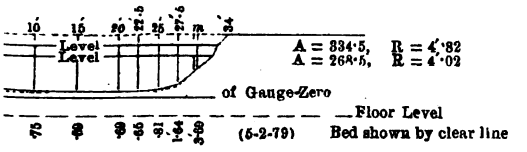
AL—KAMHERA REACH.



Distributary, Disch. for Discharge.
adworks of the Branch Canal.



- SECTIONS
an inch.



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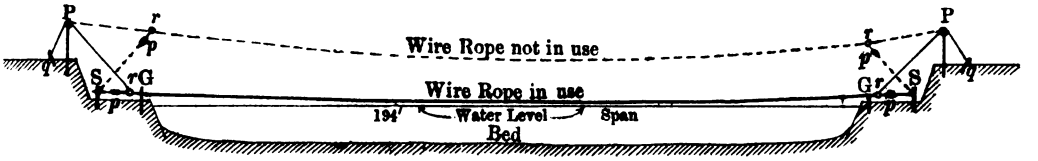
DETAILS.

Figures 1, 2, 3 are drawn for Belra Site.

FIG. 1.

WIRE ROPE ARRANGEMENTS

Scale, 50 feet to an inch.



rr.—Wire Rope
rPq—Lifting Rope
Sp—Straining Rope
P—Stand-Post
G—Guide-Post
S—Straining-Post
q—Lifting Rope Peg
r—Ring at end of Wire-Rope
P—Lifting Pulley
p—Straining Pulley

FIG. 2.

PLAN OF CROSS-SECTIONS

(obtained by sounding.)

Lines of Pendants dotted, Cross-Sections clear lines.

Scale, 250 feet to an inch.

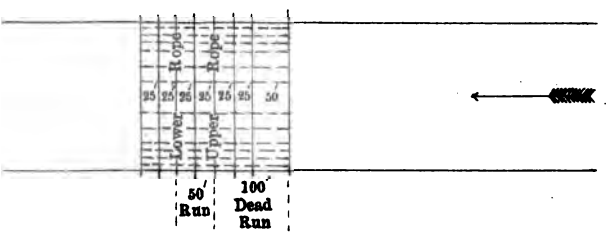


FIG. 3.

EXPERIMENT ON LENGTH OF RUN

PLAN OF ROPES

Scale, 250 feet to an inch.

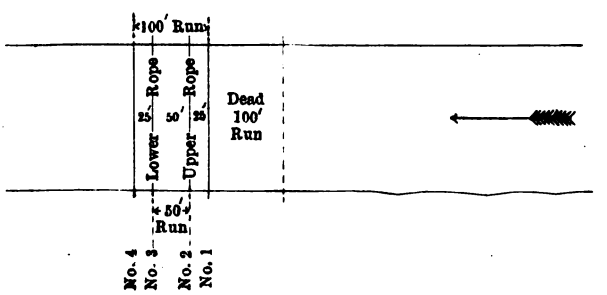
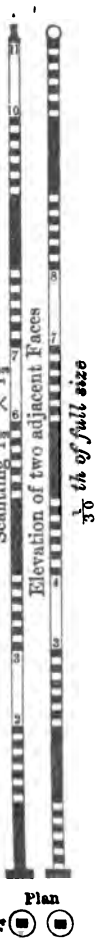


FIG. 4.

SOUNDING ROD



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SURFACE SLOPE.

ROORKEE REACH

Horizontal Scale, 1½ *miles to an inch.*

Vertical Scale, 2 *feet to an inch.*

REFERENCES.

Bold figures (19) denote miles from Head of Canal; Br. stands for Bridge.

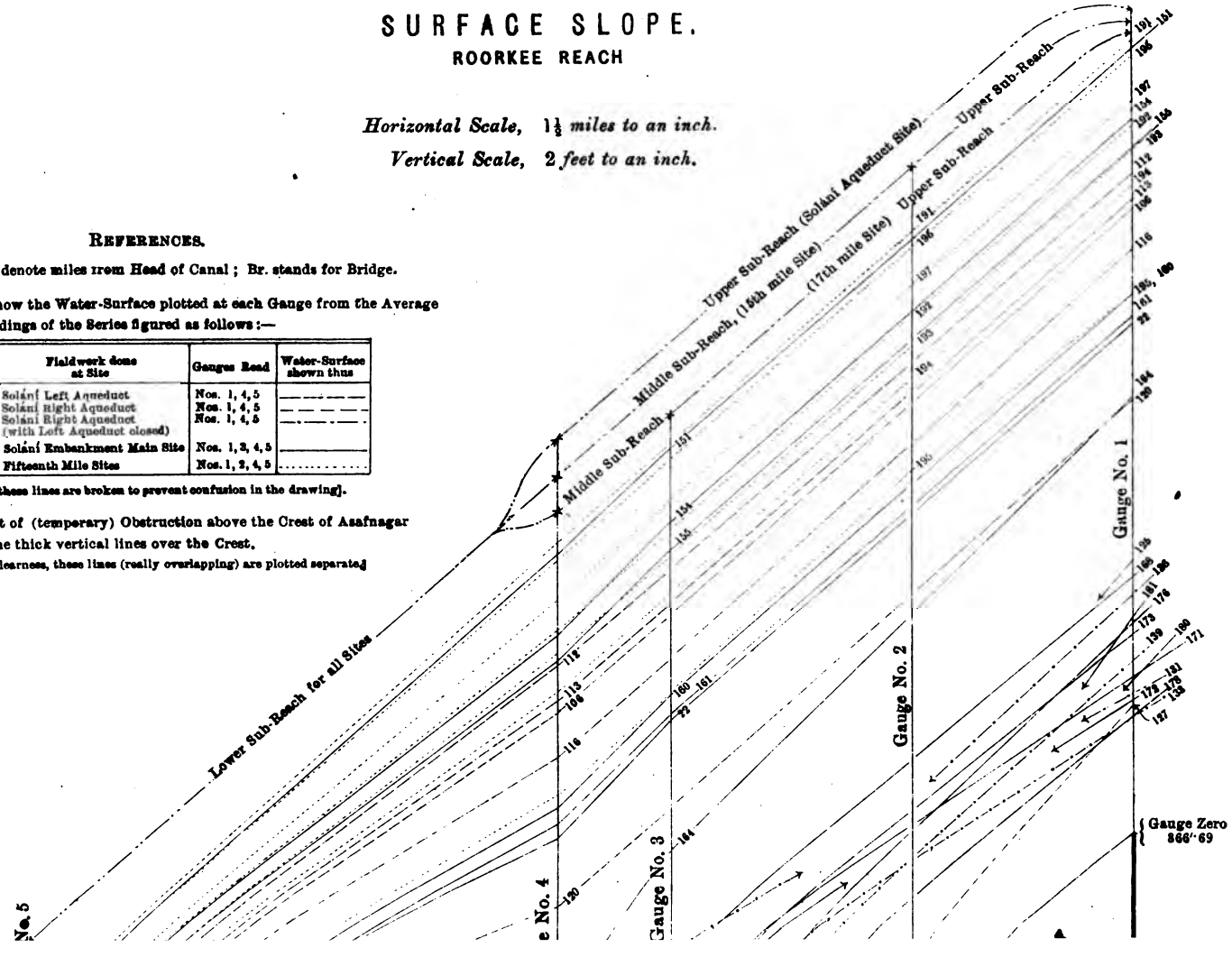
The sloping lines show the Water-Surface plotted at each Gauge from the Average Gauge-Readings of the Series figured as follows:—

Serial No. between	Fieldwork done at Site	Gauges Read	Water-Surface shown thus
101 — 107	Solání Left Aqueduct	Nos. 1, 4, 5	———
108 — 127	Solání Right Aqueduct	Nos. 1, 4, 5	– – – –
131 — 139	Solání Right Aqueduct (with Left Aqueduct closed)	Nos. 1, 4, 5	—·—·—
22 and 151 — 181	Solání Embankment Main Site	Nos. 1, 2, 3, 4, 5	———
191 — 197	Fifteenth Mile Sites	Nos. 1, 2, 4, 5	·····

[Several of these lines are broken to prevent confusion in the drawing].

The Average Height of (temporary) Obstruction above the Crest of Asafnagar Falls is shown by the thick vertical lines over the Crest.

(*N.B.* For sake of clearness, these lines (really overlapping) are plotted separated)



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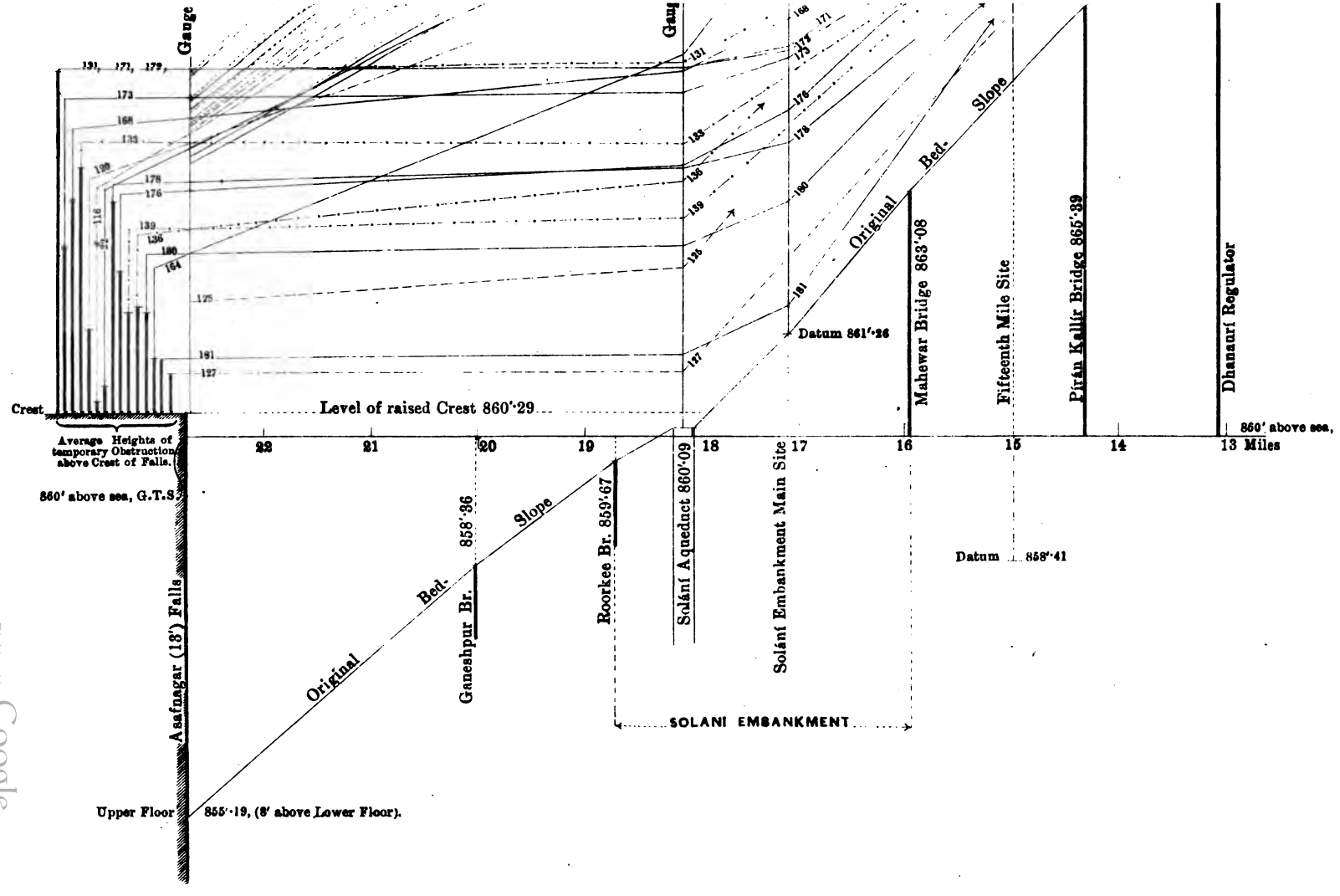

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PLATE IX.

SURFACE SLOPE.

JAOLI REACH

Horizontal Scale, 1½ miles to an inch.

Vertical Scale, 2 feet to an inch.

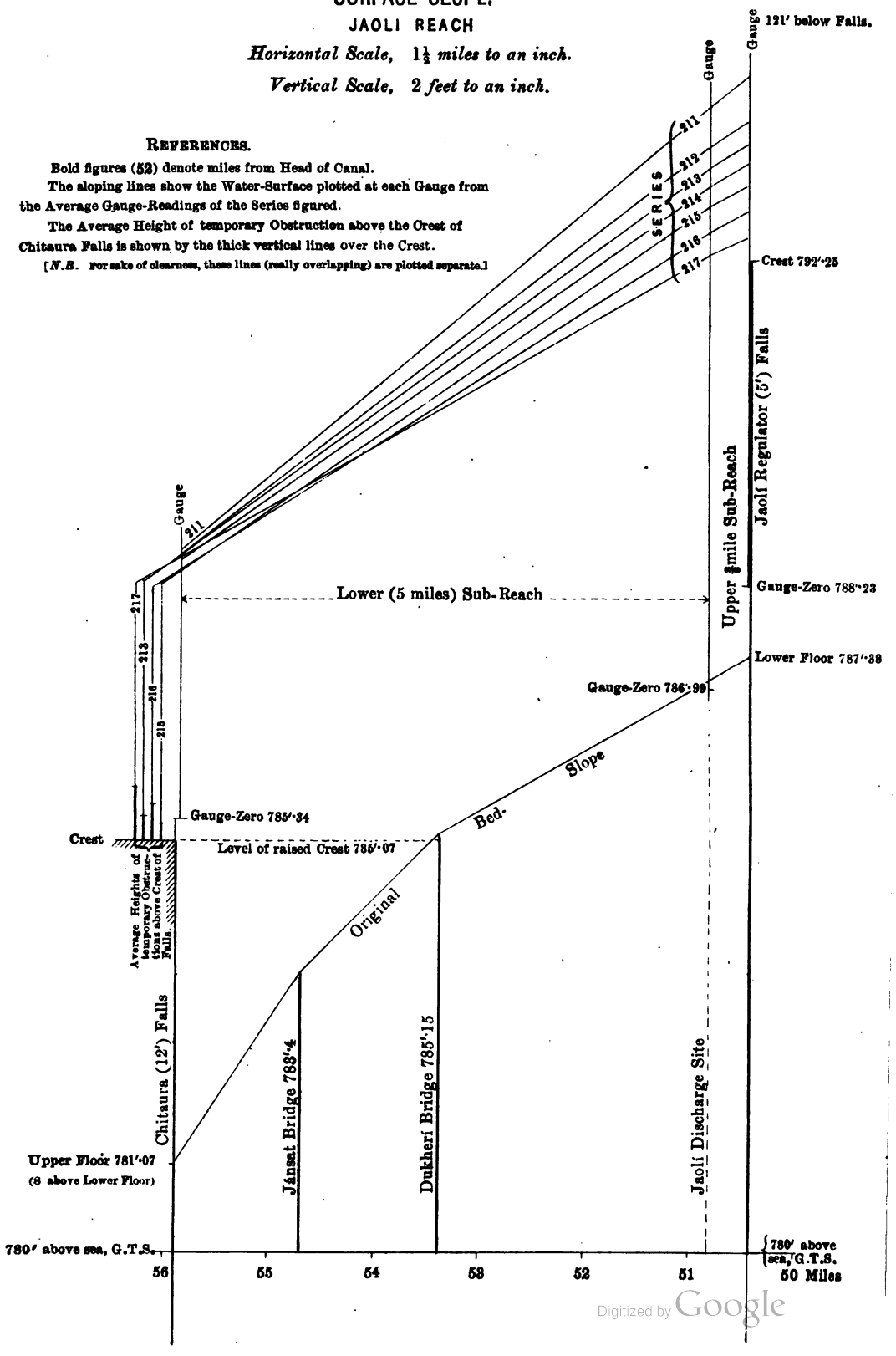

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PLATE X

CONVEXITY OF WATER-SURFACE.

SOLANI EMBANKMENT MAIN SITE

FIG. 3.
SPECIAL
LEVELLING STAFF
$\frac{1}{10}$th of full size

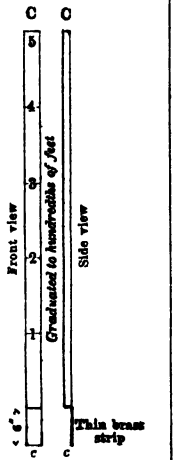


FIG. 1.
PLAN
Scale of 250 feet to an inch.

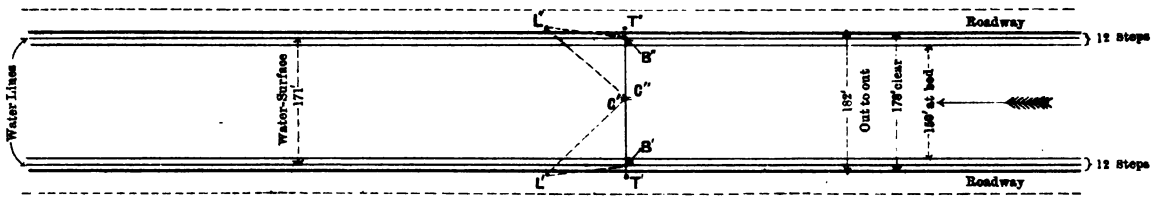


FIG. 4.

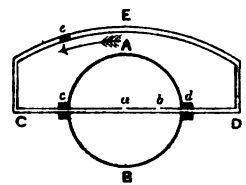
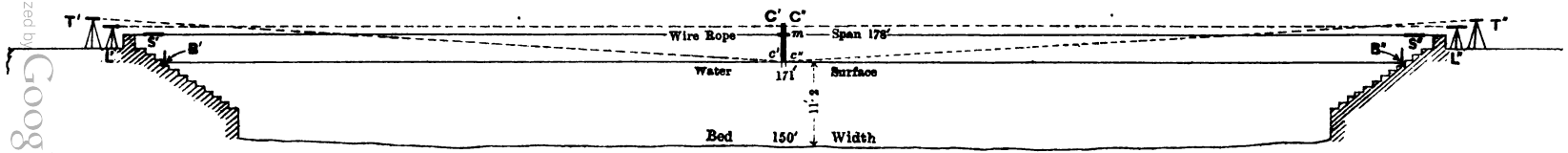


FIG. 2.
CROSS-SECTION ON T'T''
Scale of 25 feet to an inch.



S', S'' Straining Screws; T', T'' Theodolites; L', L'' Spirit Levels; C'c', C''c'' Levelling Staves; c', c'' thin ($\frac{1}{10}$) Strips at feet of Staves; B', B'' thin ($\frac{1}{10}$) brass Foot Rules; m Saddle.

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DOUBLE—FLOATS.

FIG. 1.
3″ BALL PATTERN

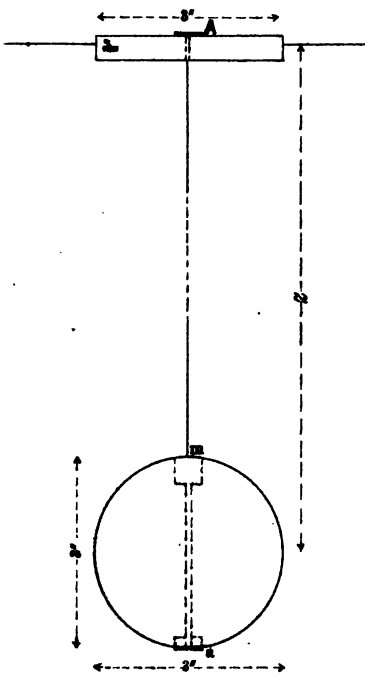


FIG. 2.
1⅛″ SHELL PATTERN

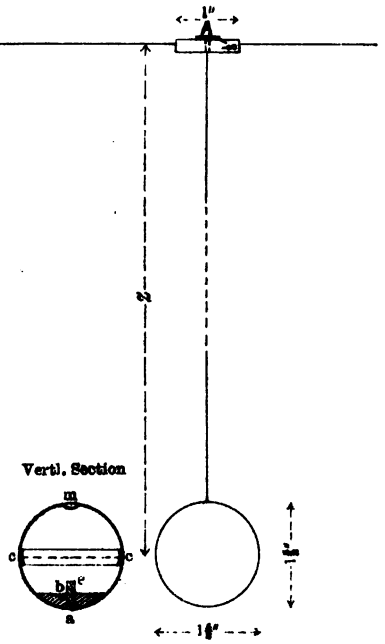
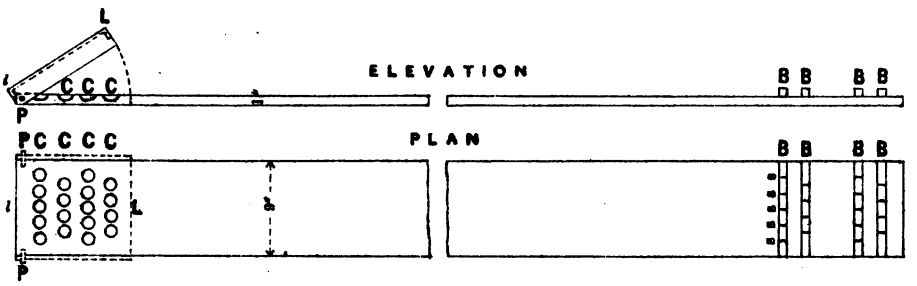


FIG. 3.
PLANK-TRAY



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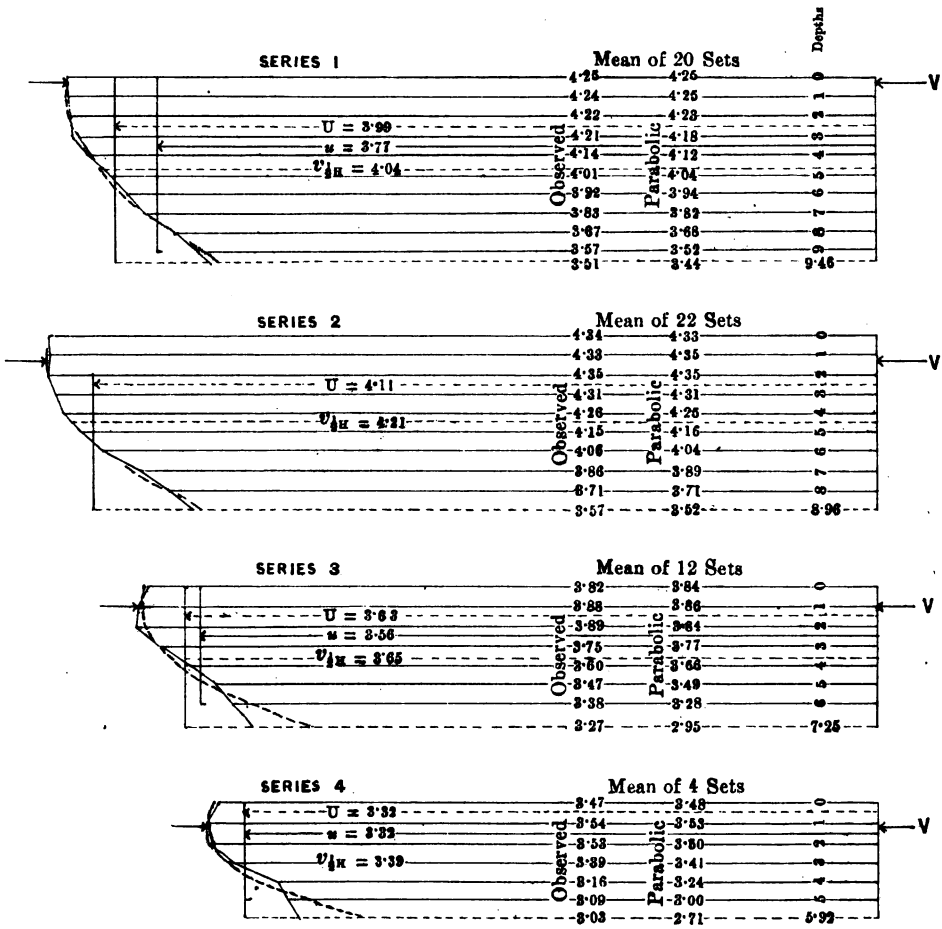
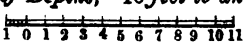
CENTRAL VERTICAL VELOCITY CURVES.

SOLANI LEFT AQUEDUCT



SCALES FOR PLATES XII TO XVIII

Scale of Depths, 10 *feet to an inch.*



Velocity-Scale, 1 *foot per second to an inch.*

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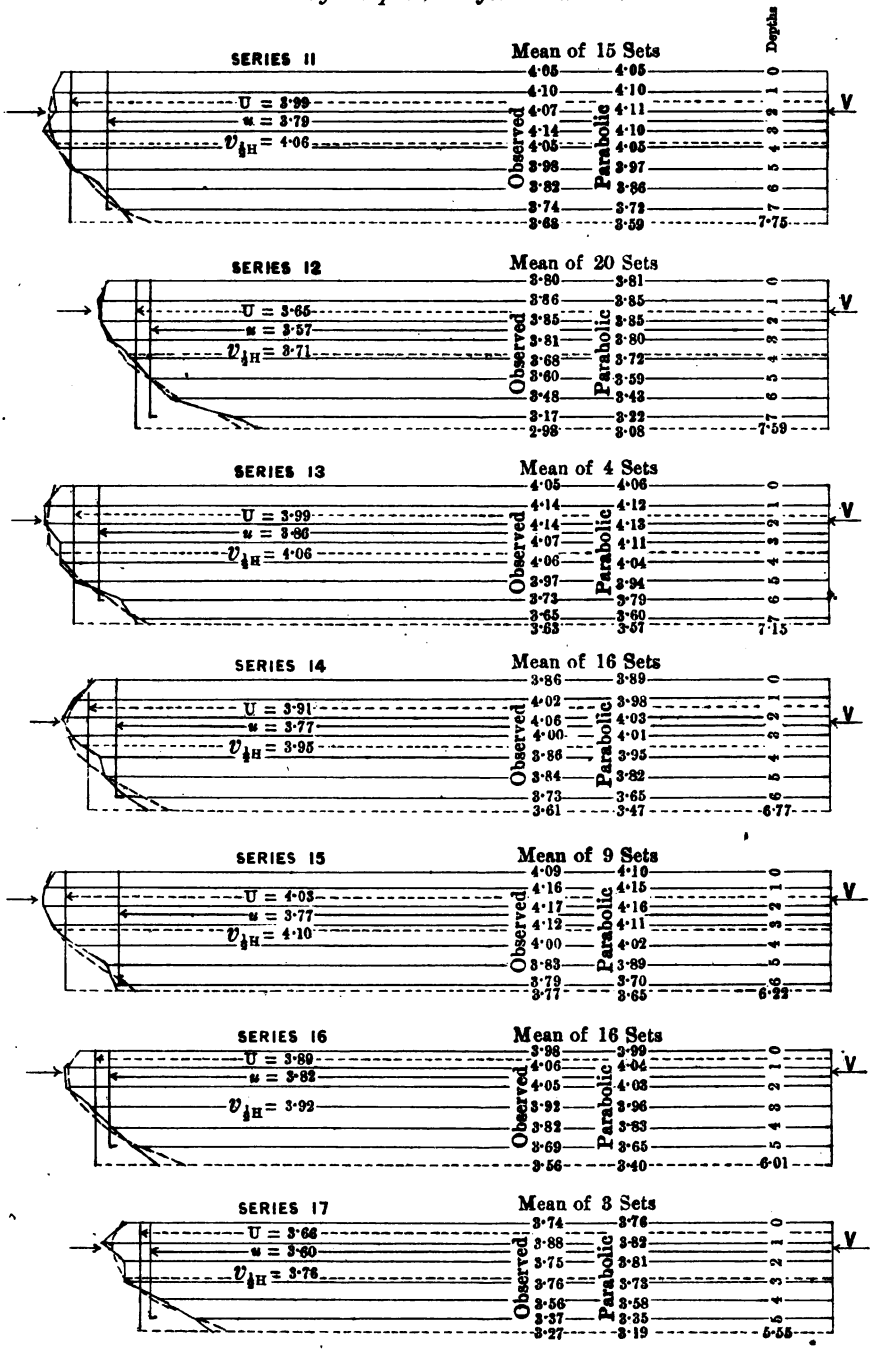
CENTRAL VERTICAL
SOLANI RIGHT

Scale for depths. 10 *feet to an inch.*



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VELOCITY CURVES.
AQUEDUCT

Velocity-Scale, 1 foot per second to an inch.

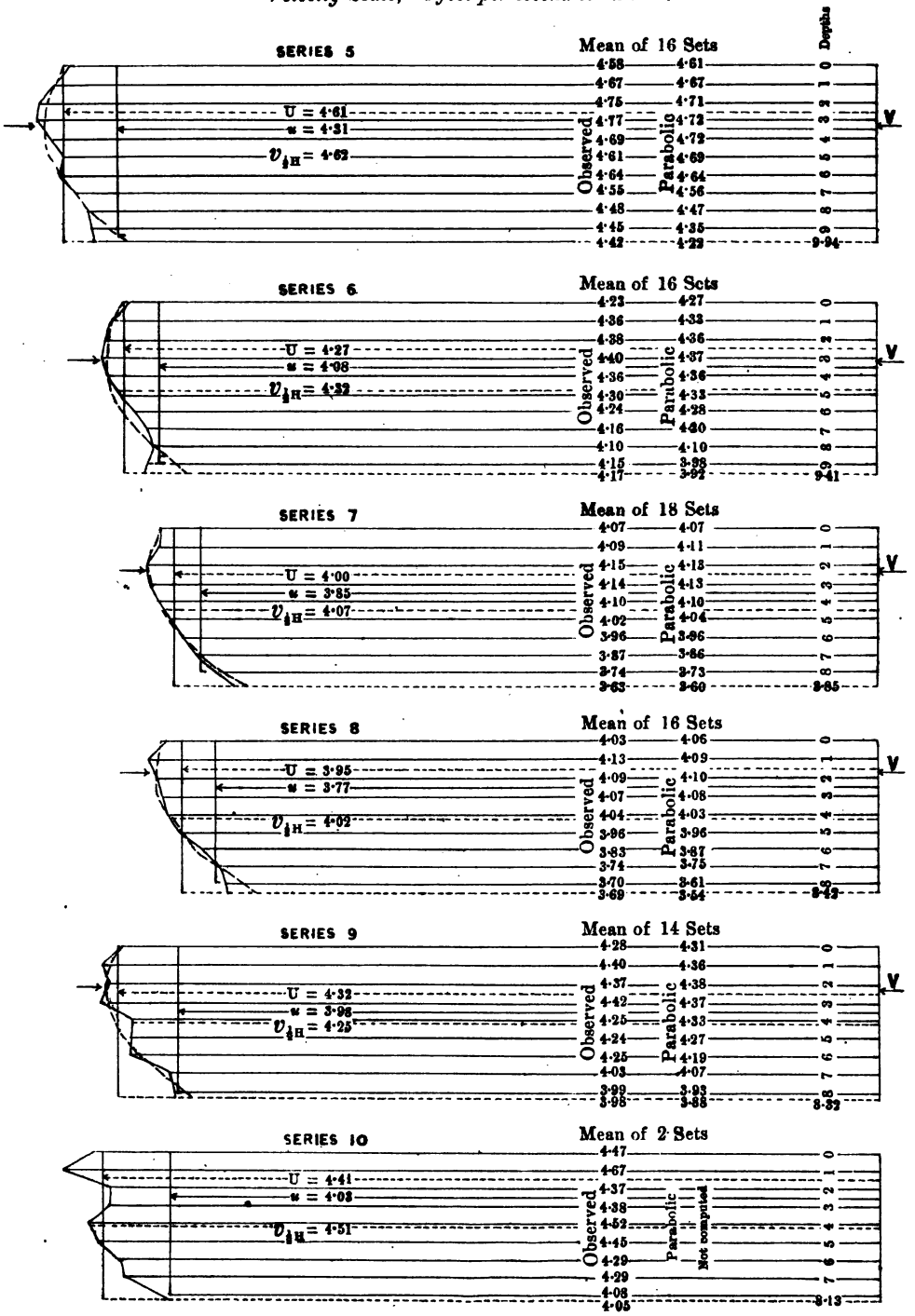

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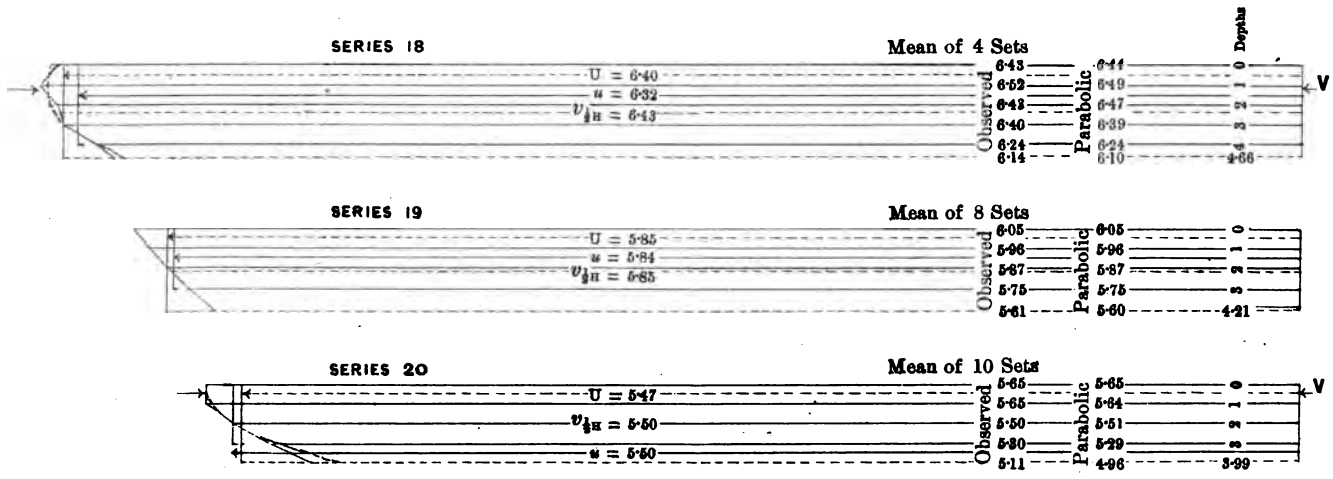
PLATE XIV.

CENTRAL VERTICAL VELOCITY CURVES.

SOLANI RIGHT AQUEDUCT

[LEFT AQUEDUCT CLOSED]



Scale for depths, 10 *feet to an inch.*

Velocity-Scale, 1 *foot per second to an inch.*

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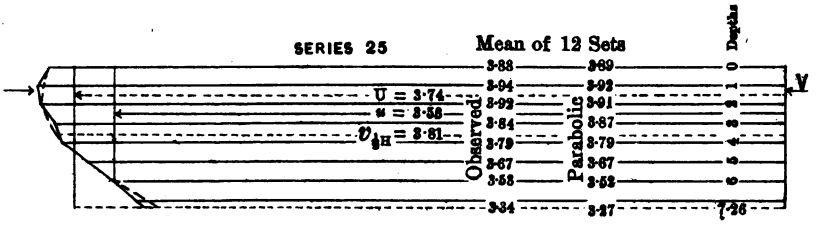
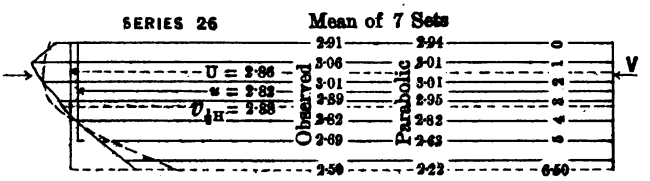
CENTRAL VERTICAL

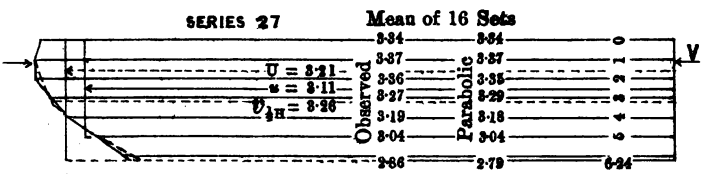
SOLANI EMBANK-

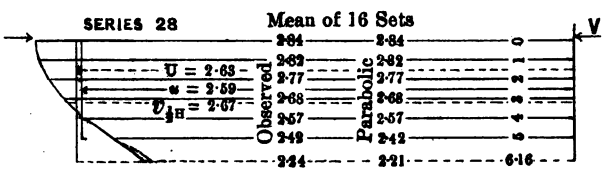
Scale for depths,

Velocity-Scale, 1 *foot*









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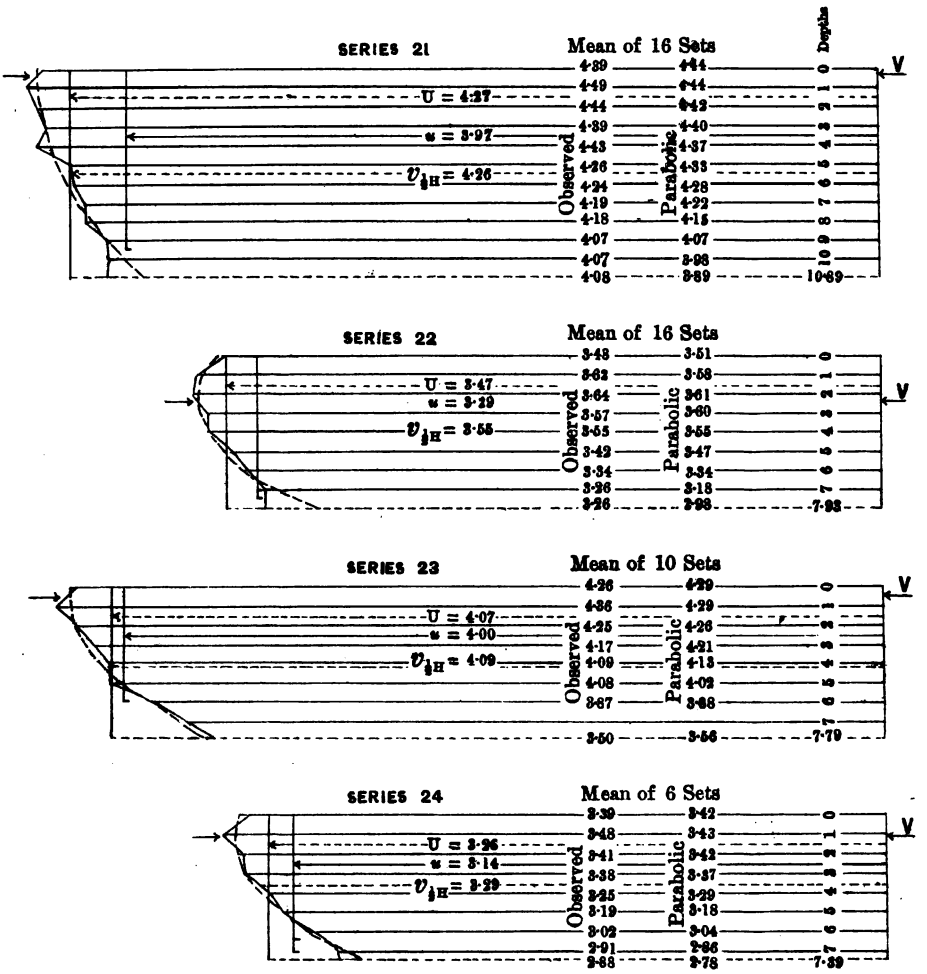
VELOCITY CURVES.

MENT MAIN SITE

PLATE XV.

10 *feet to an inch.*

per second to an inch.



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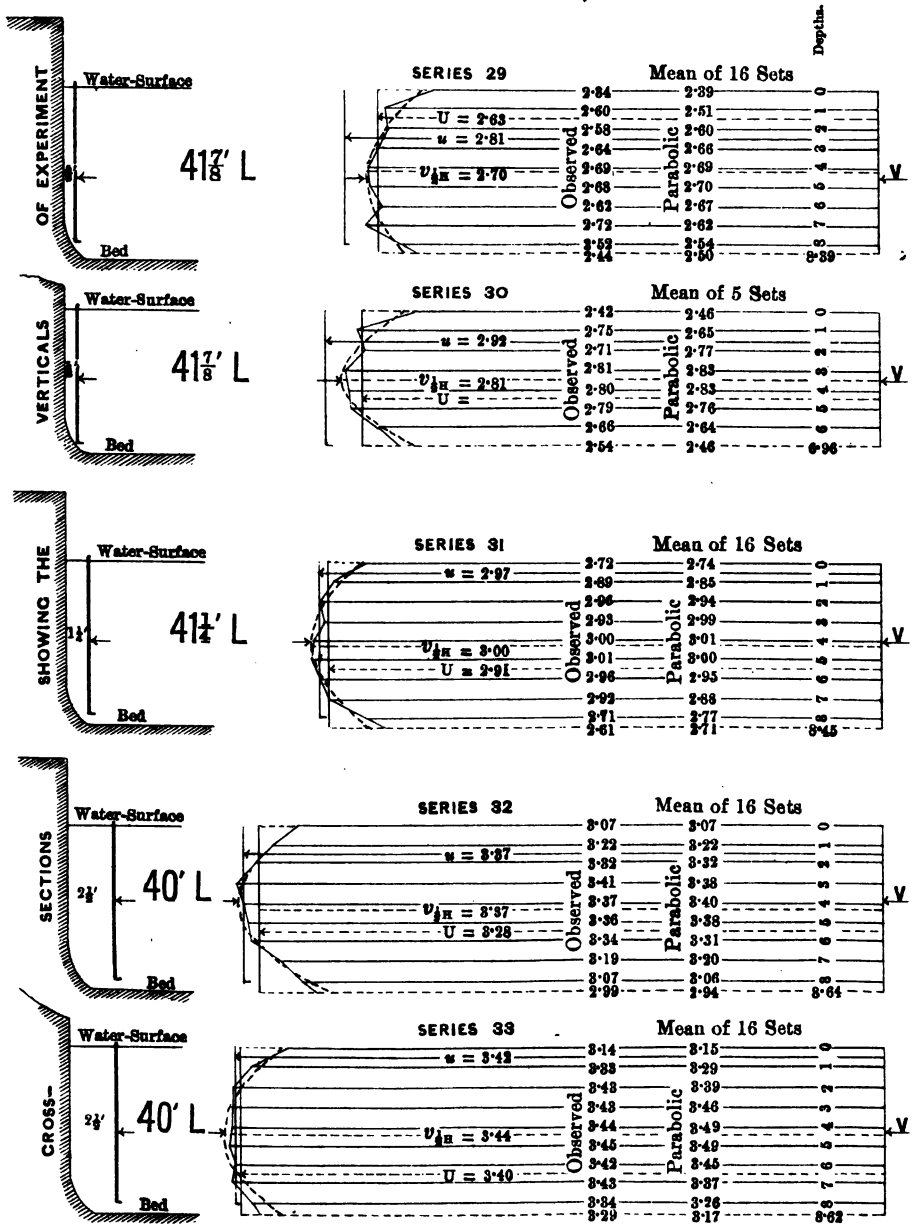
NON-CENTRAL VERTICAL VELOCITY CURVES.

SOLANI RIGHT AQUEDUCT

Scale for Cross-Sections and depths, 10 *feet to an inch.*

Velocity-Scale, 1 *foot per second to an inch.*

N. B.—The arrows on the Cross-Sections show the positions of the lines of max. velocity (V) of each Series.



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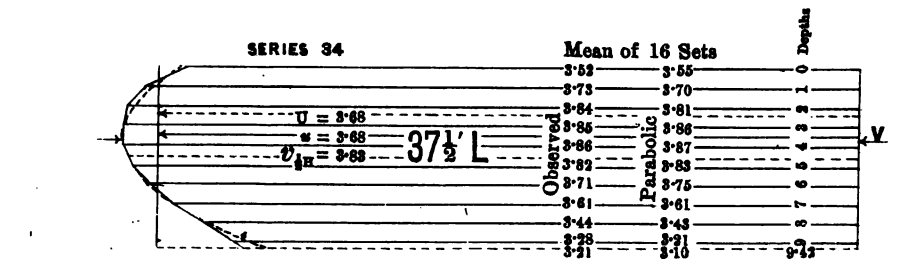
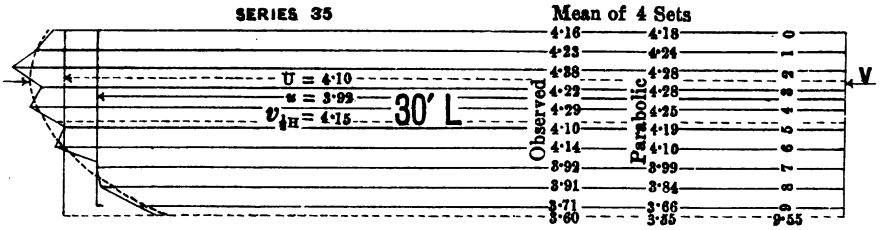
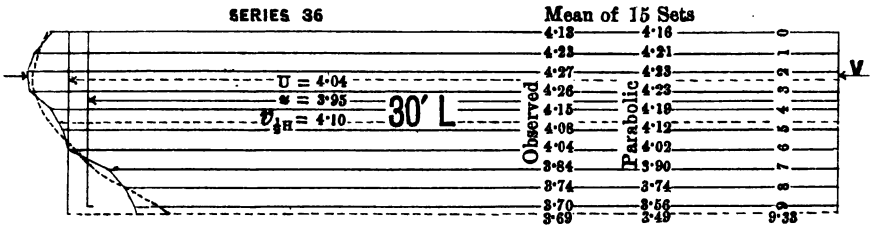
NON-CENTRAL VERTICAL

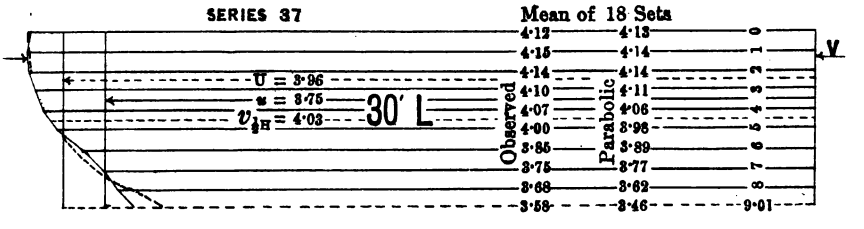
SOLANI RIGHT

Scale for depths, 10 *feet to an inch.*





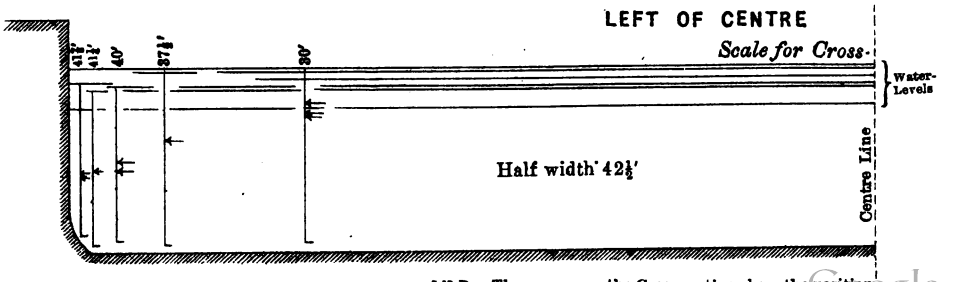




CROSS-SECTION SHOWING THE

LEFT OF CENTRE

Scale for Cross-



[*N.B.* The arrows on the Cross-section show the position

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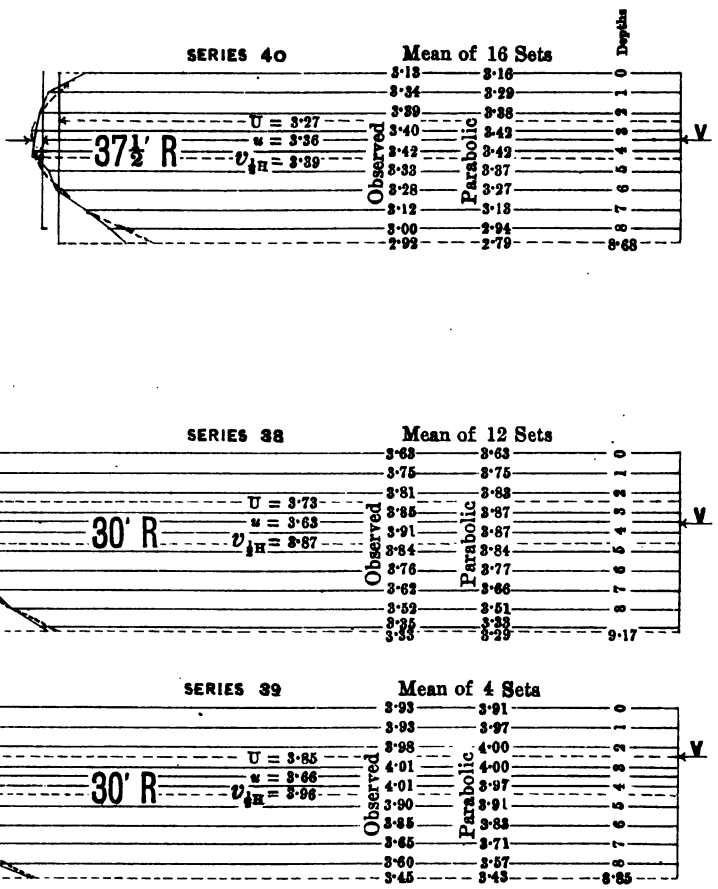
VELOCITY CURVES.

AQUEDUCT

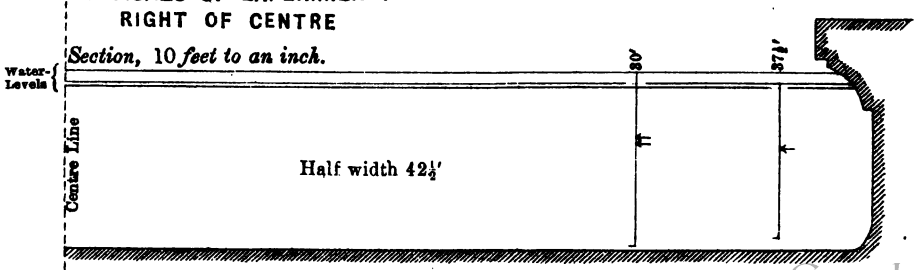
Velocity-Scale, 1 *foot per second to an inch.*



VERTICALS OF EXPERIMENT.

RIGHT OF CENTRE

Section, 10 *feet to an inch.*



of the lines of maximum velocity (V) of each Series].

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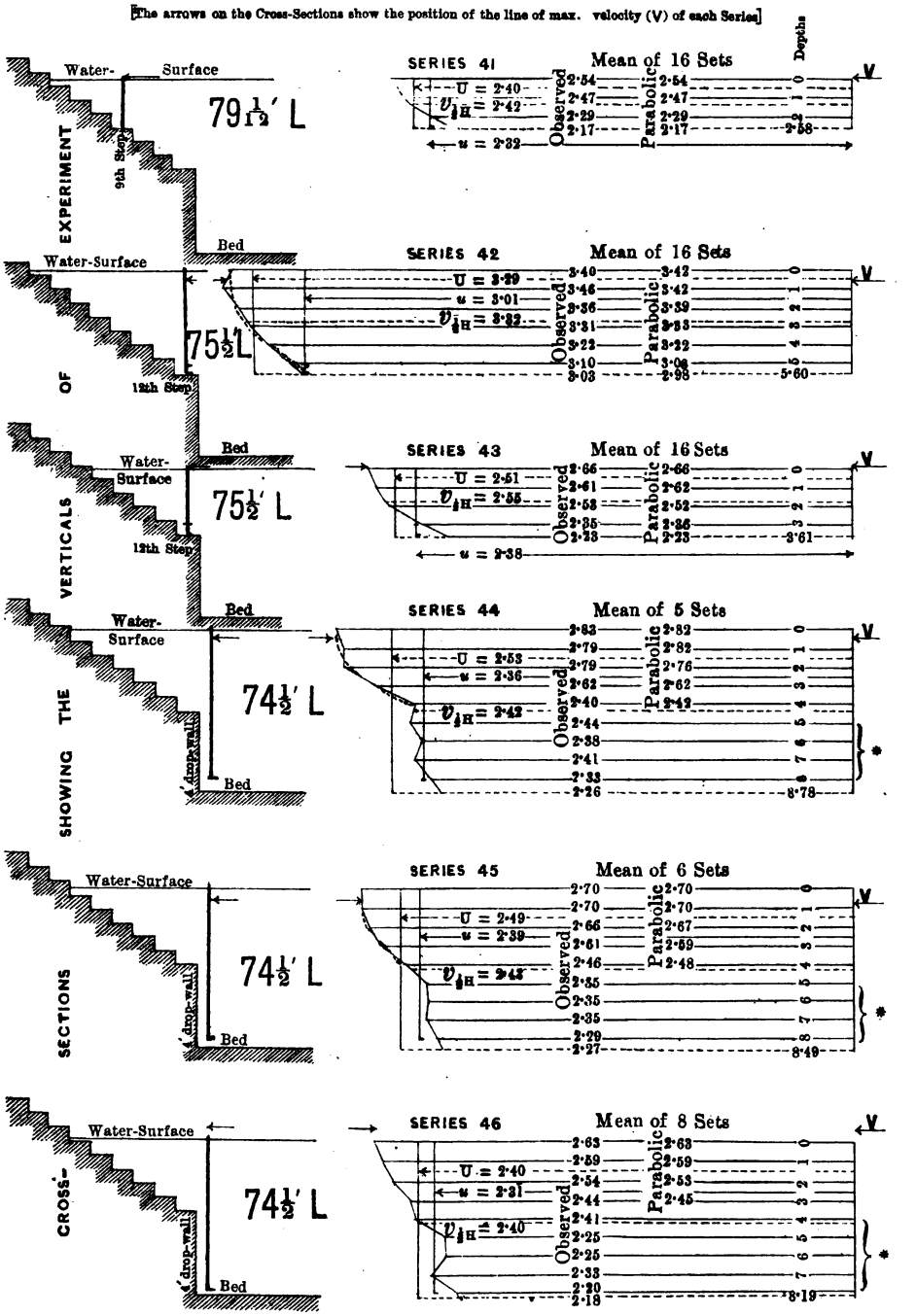
NON-CENTRAL VERTICAL VELOCITY CURVES.

SOLANI EMBANKMENT MAIN SITE

Scale for Cross-Sections and depths, 10 *feet to an inch.*
Velocity-Scale, 1 *foot per second to an inch.*

[The arrows on the Cross-Sections show the position of the line of max. velocity (V) of each Series]



* [Parabolic velocity-ordinates not computed for the 74½' L. vertical below level of lowest step].

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VERTICAL VELOCITY-CURVES.

INSTRUMENTAL DISTORTION

Observation-Curves ---------- True Curves ———

FIG. ii *a*

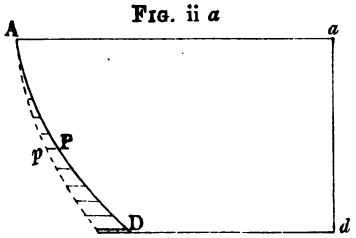


FIG. ii *b*

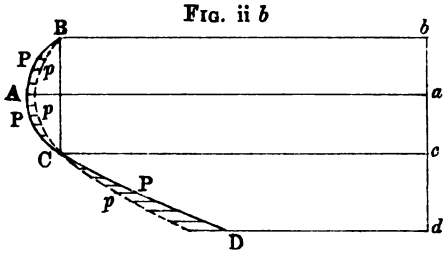


FIG. iii *a*

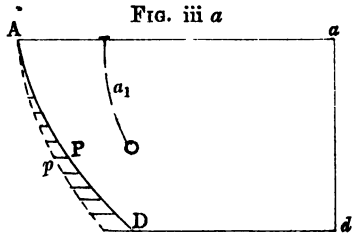


FIG. iii *b*

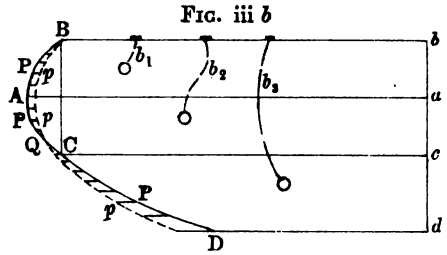


FIG. v *a*

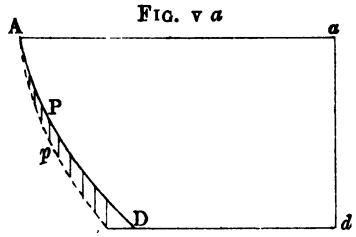


FIG. v *b*

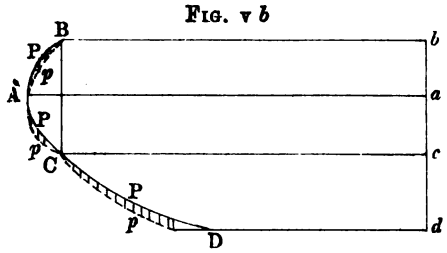


FIG. vi *a*

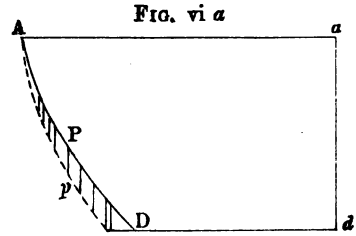


FIG. vi *b*

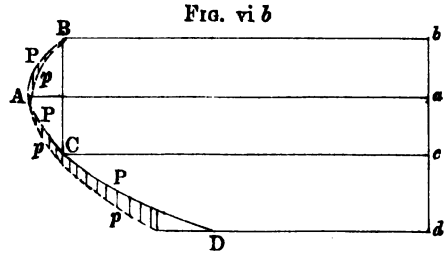


FIG. 5 *a*

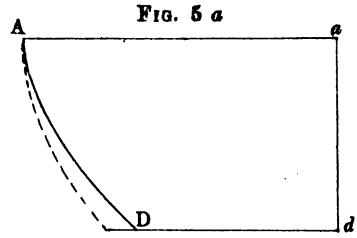
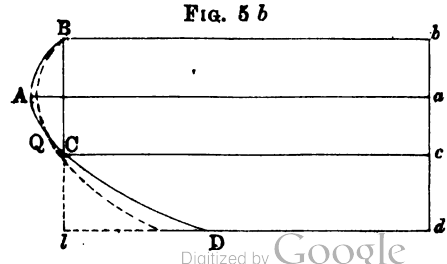


FIG. 5 *b*



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Vertical Velocity Curves, FIGS. 1 *to* 5.

References for Fig. 3; $bB = v_0 = cC$, $aA = V$, $pP = v$, $mM = v_{\frac{1}{2}H}$, $dD = v_H$, $bc = 2Z$, $ba = Z$, $bp = z$, $bM = \frac{1}{2}H$, $bd = H$

FIG. 1.

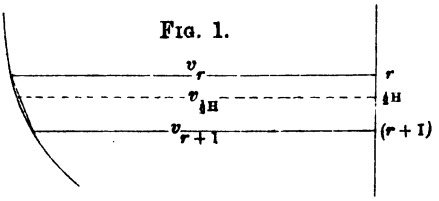


FIG. 2.

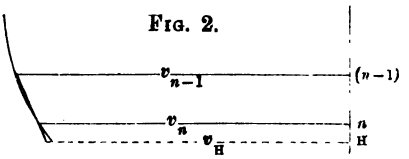


FIG. 3.

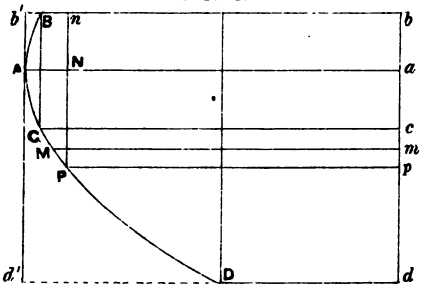


FIG 4.

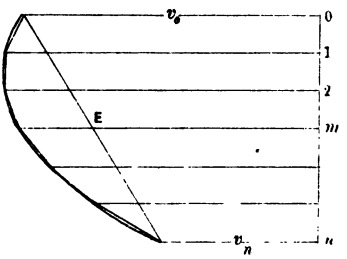


FIG. 6.

Connexion by Levelling of opposite banks of Canal.

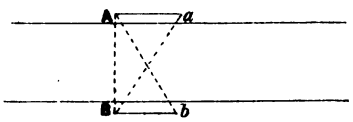
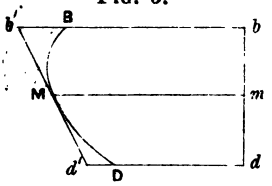


FIG. 5.



Discharge in Side-Spaces, FIGS. 7, 8.

Fig. 7.

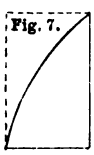
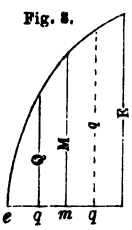


Fig. 8.



Cubic Discharge in Side-Spaces, FIGS. 9. *to* 10.

Fig. 9.

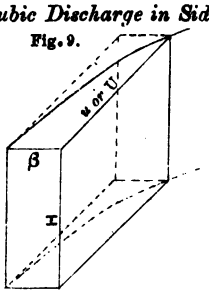


Fig. 10.

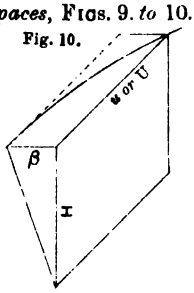
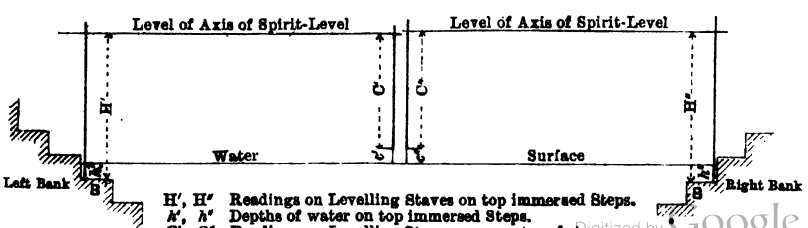


FIG. 11.

Experiment on Convexity of Water-Surface.



H', H'' Readings on Levelling Staves on top immersed Steps.
h', h'' Depths of water on top immersed Steps.
C', C'' Readings on Levelling Staves over centre of stream.
c', c'' Readings on strips at foot of central Staves.

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CENTRAL VERTICAL VELOCITY CURVES.

VARIATION OF ELEMENTS

SOLANI AQUEDUCT SITES

Ordinates, { Left Aqueduct, thick lines, Right Aqueduct, thin lines.

N.B. The ordinates are broken to prevent confusion in the drawing.

Explanation of symbols		Curve
Abscisse,	H = Depth of water	clear ———
Ordinates,	F_1 = Surface-Fall in upper Half Reach	clear ———
	F_2 = Surface-Fall in 1 mile below Site, (Plate XXII)	dotted .....
	F_3 = Surface-Fall in lower Half Reach	clear ———
	V = Maximum Velocity (in velocity-parabola)	clear ———
	v_0 = Surface Velocity	dashes — — —
	U = Mean Velocity	chain dotted —.—.—
	v_H = Bed Velocity	clear ———
	u = Rod Velocity	dotted .....
	Z = Depth of Maximum Velocity Line	clear ———
	ζ = Proportionate Depth of ditto = Z ÷ H	dotted .....
	p = Parameter of velocity-parabola	chain dotted —.—.—

Scales.

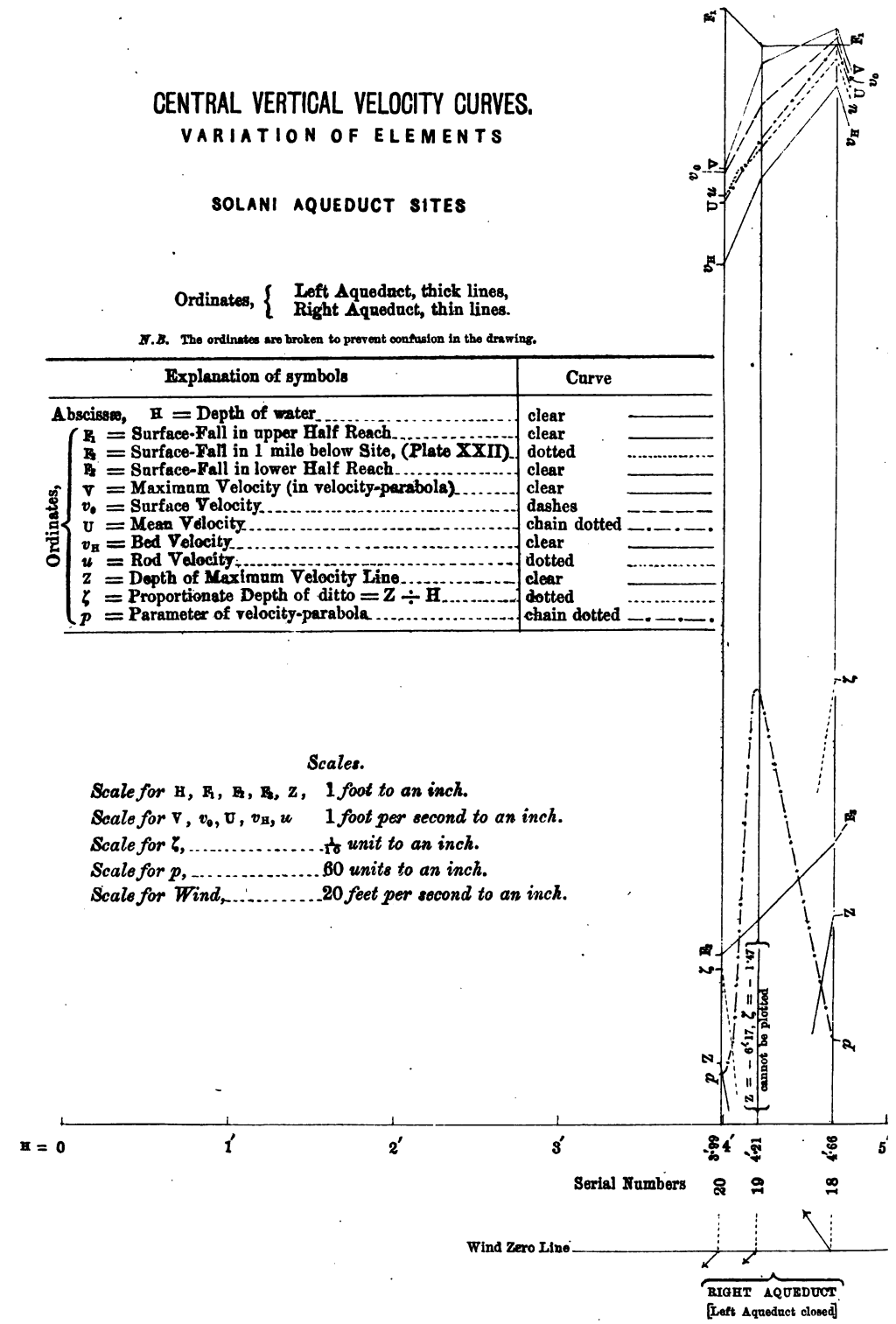
Scale for H, F_1, F_2, F_3, Z, 1 *foot to an inch.*

Scale for V, v_0, U, v_H, u 1 *foot per second to an inch.*

Scale for ζ, ... $\frac{1}{10}$ *unit to an inch.*

Scale for p, ... 30 *units to an inch.*

Scale for Wind, ... 20 *feet per second to an inch.*



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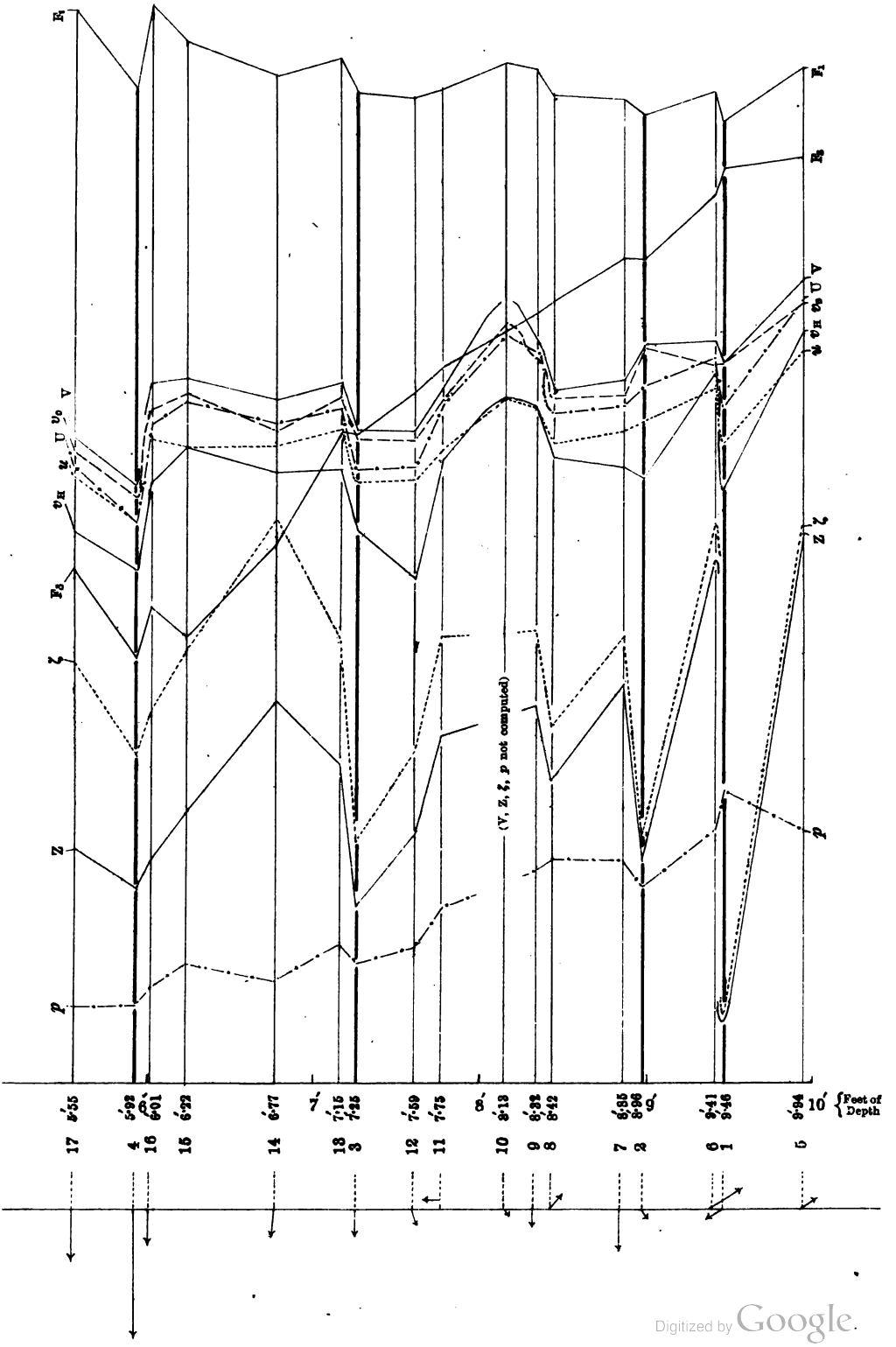

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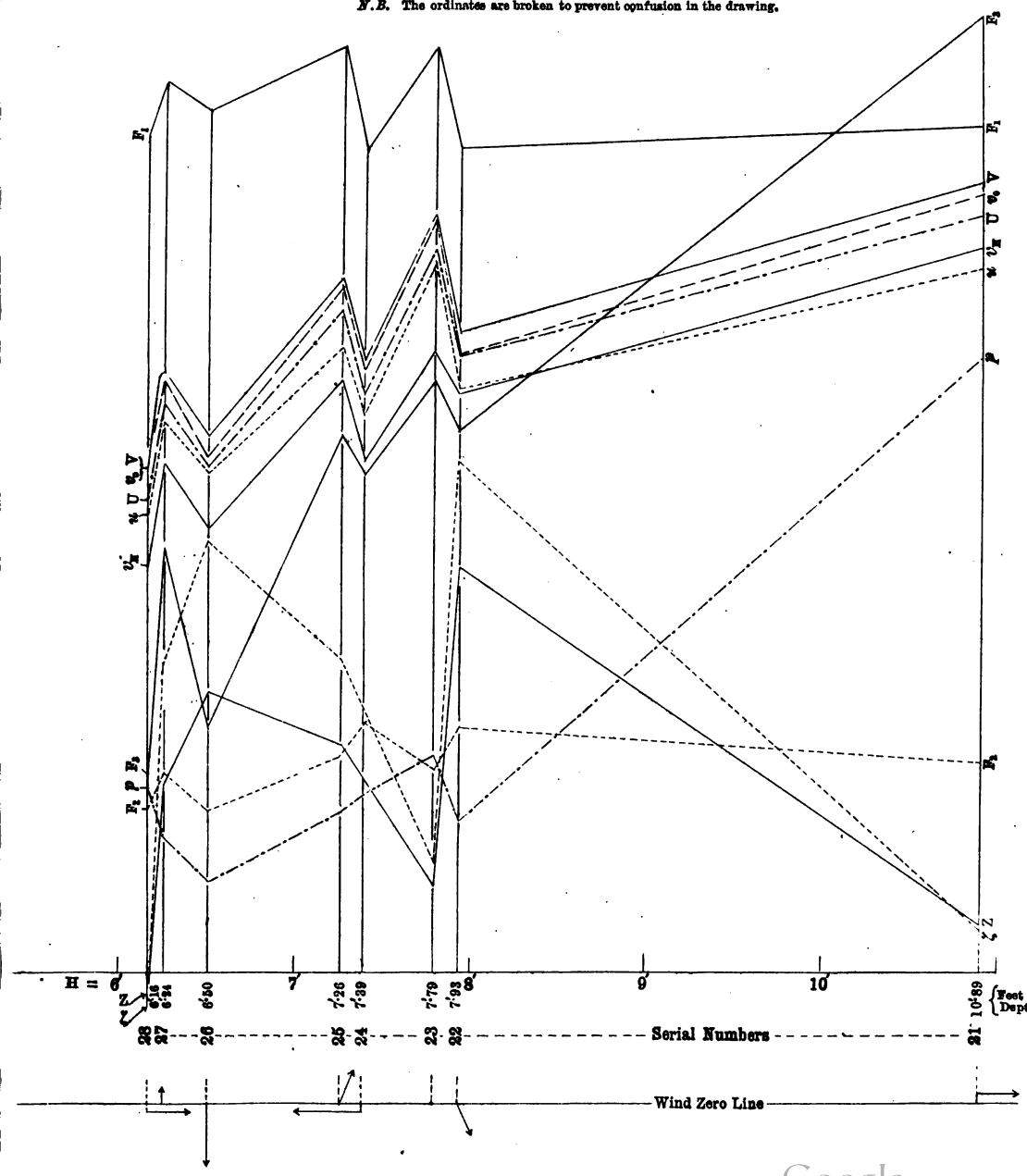
CENTRAL VERTICAL VELOCITY CURVES.

VARIATION OF ELEMENTS

SOLANI EMBANKMENT MAIN SITE

[*For explanation of symbols, and for Scales, see Plate XXI*].

N.B. The ordinates are broken to prevent confusion in the drawing.



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PARAMETER CURVES.

Fig. 1.
SOLANI LEFT AQUEDUCT

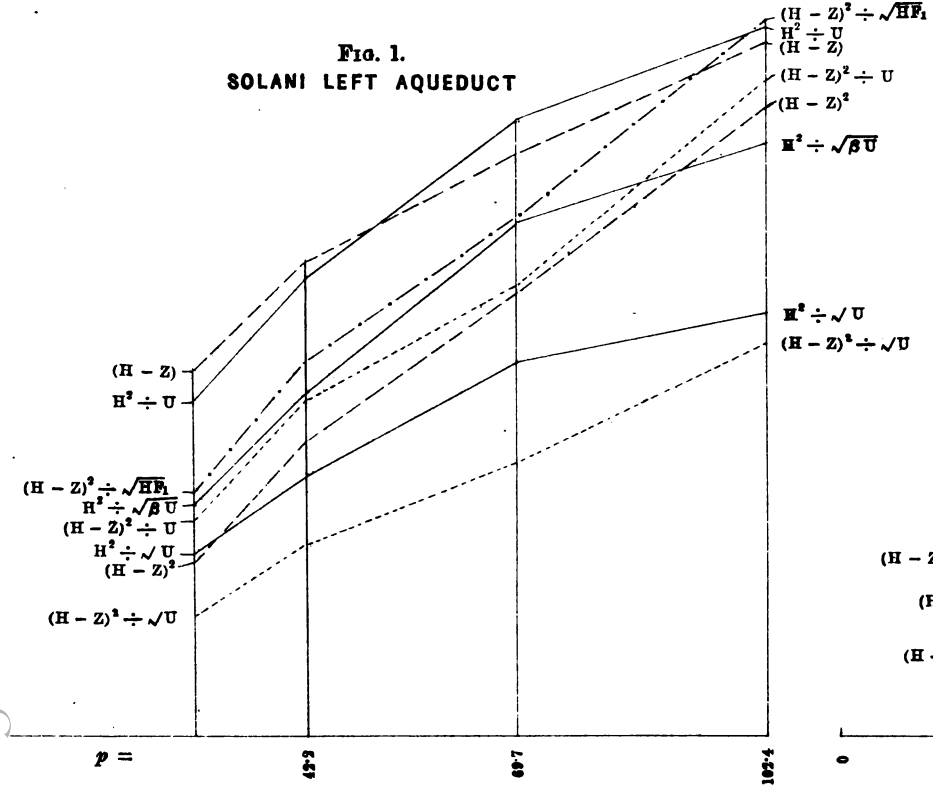
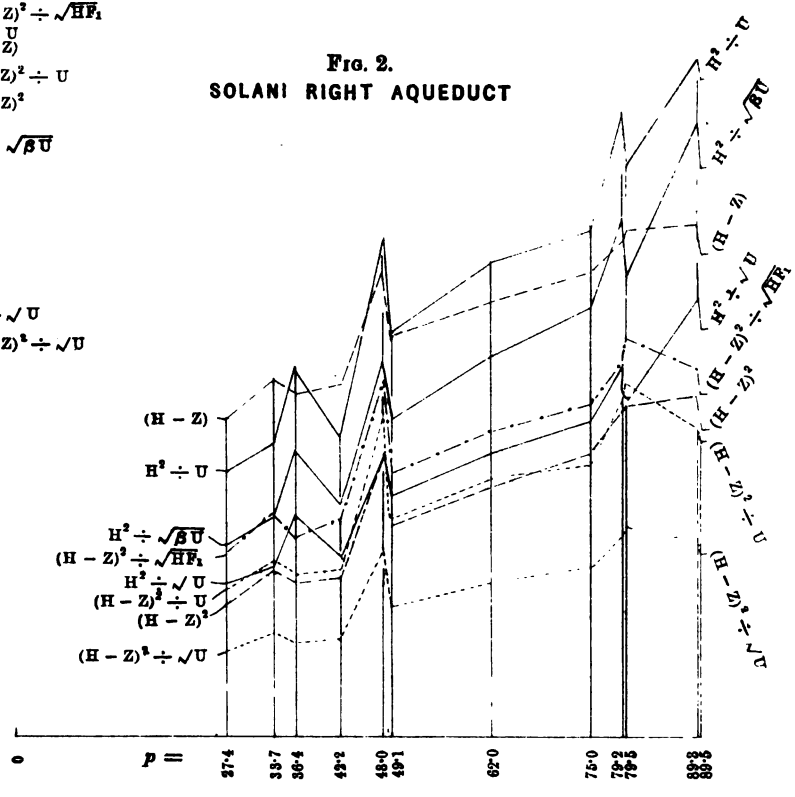


Fig. 2.
SOLANI RIGHT AQUEDUCT



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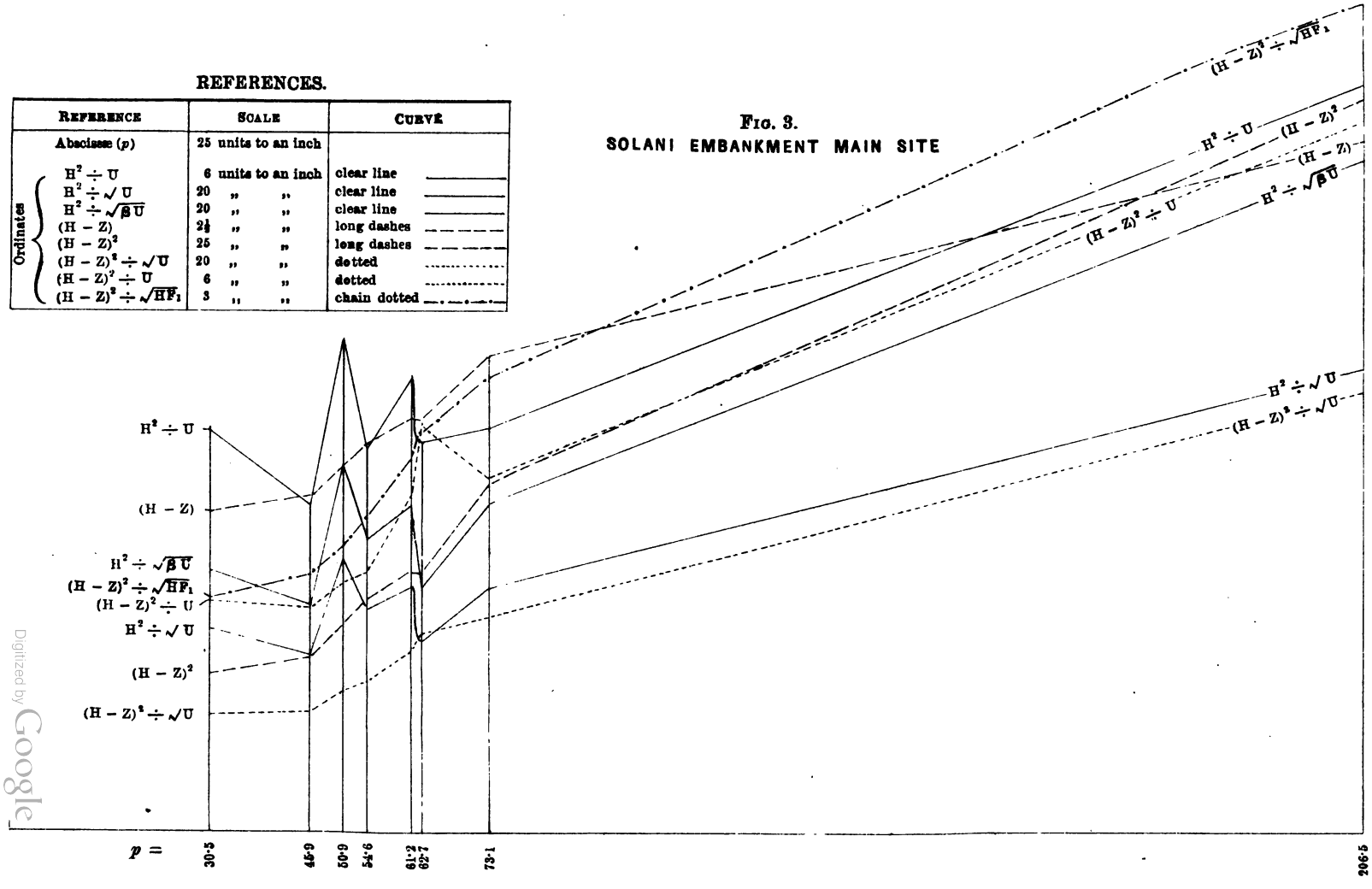
REFERENCES.

Reference		Scale		Curve
Abscisse (p)		25 units to an inch		
Ordinates	$H^2 \div U$	6 units to an inch		clear line
	$H^2 \div \sqrt{U}$	20	,, ,,	clear line
	$H^2 \div \sqrt{\beta U}$	20	,, ,,	clear line
	$(H - Z)$	$2\frac{1}{2}$	,, ,,	long dashes
	$(H - Z)^2$	25	,, ,,	long dashes
	$(H - Z)^2 \div \sqrt{U}$	20	,, ,,	dotted
	$(H - Z)^2 \div U$	6	,, ,,	dotted
	$(H - Z)^2 \div \sqrt{HF_1}$	3	,, ,,	chain dotted

FIG. 3.

SOLANI EMBANKMENT MAIN SITE



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VARIOUS INSTRUMENTS.

PLATE XXIV.

FIG 1. FIG 2

On various Scales,- (1/12th, 1/20th, 1/25th, 1/30th Sizes).

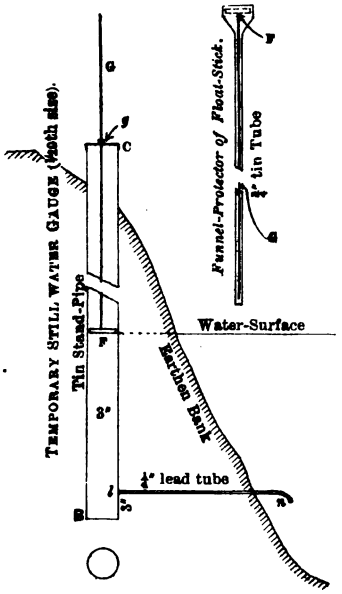


FIG. 10.

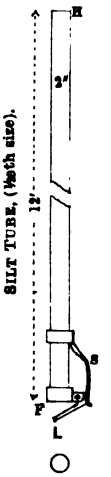
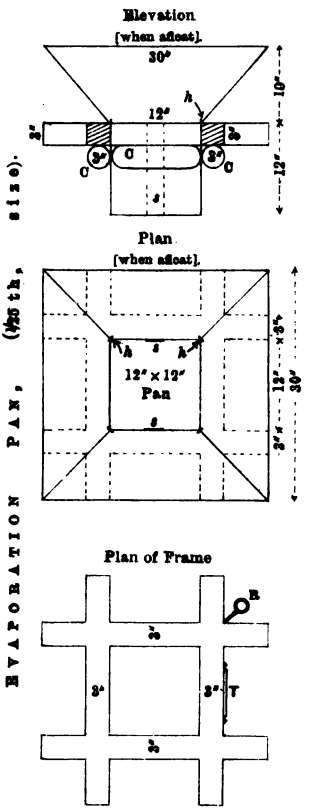


FIG. 11.



FREE WATER-LEVEL.

Use of Brass Foot-Rule (B).

FIG. 3.

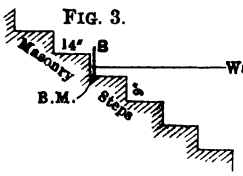
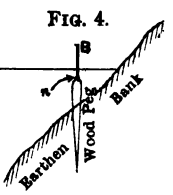


FIG. 4.



MEAN VELOCITY—RODS.

FIG. 9.

TEST-TUBE.
[*for Rods*].

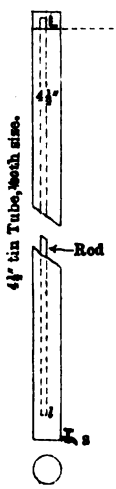


FIG. 5.

FIG 6.

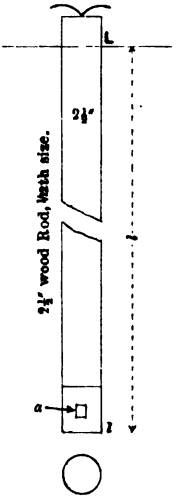


FIG. 7.

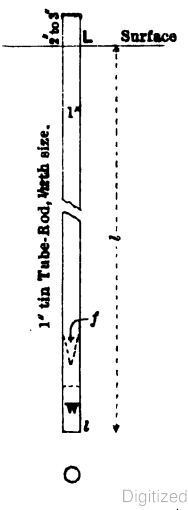
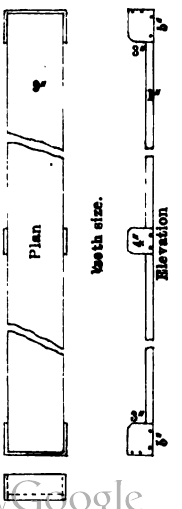


FIG. 8.

PLANK-TRAY.
[*for Rods*].



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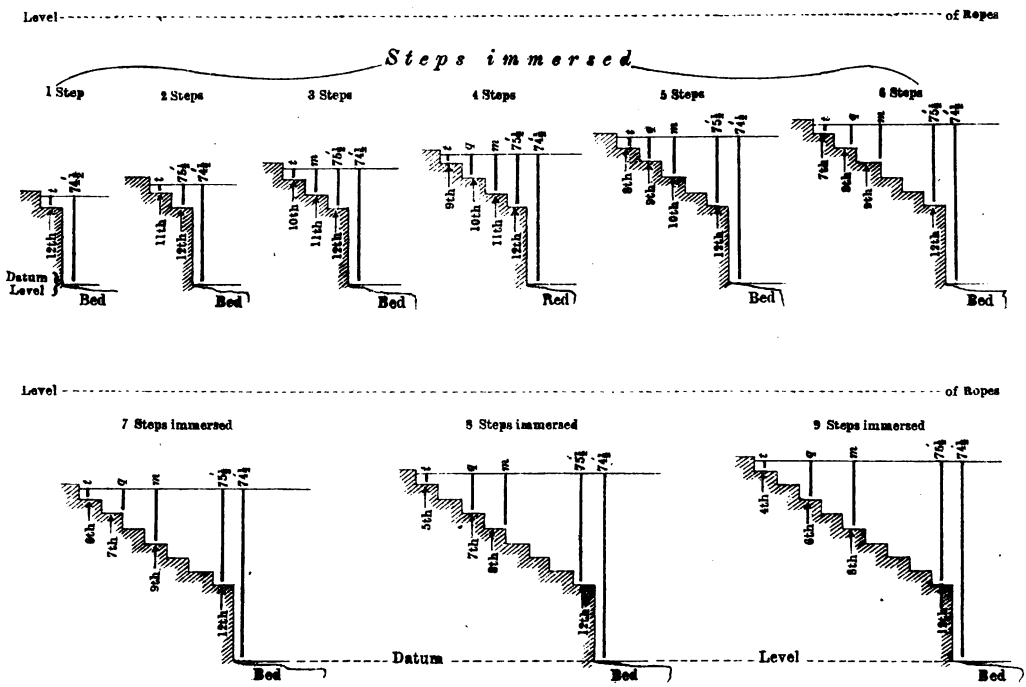
SIDE-SPACE—FLOAT-COURSES.

[Shewing the arrangement of Float-Courses over stepped and sloping banks, with the Side-Spaces varying in width as the water rises and falls].

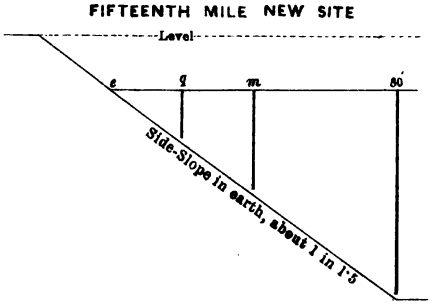
The Water-Surface is shown by a clear line. The thick vertical lines shew the Rods as in use.
The upper dotted line shows the level of the Upper and Lower Ropes,
Symbols:—*e*, Edge; *t*, Top (immersed) Step; *m*, middle (of Side-Space); *q*, Quadrisection (of Side-Space).
[*N.B.* Surface-Floats were used over the top step (*t*) when the water was very shallow thereon].

SOLANI EMBANKMENT MAIN SITE

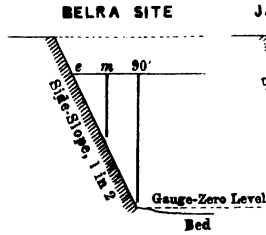
[The ordinal numbers (as 9th) shew the number of each Step reckoned from the top Step].



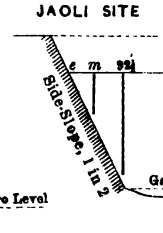
FIFTEENTH MILE NEW SITE



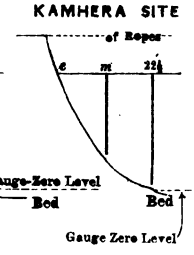
BELRA SITE



JAOLI SITE



KAMHERA SITE



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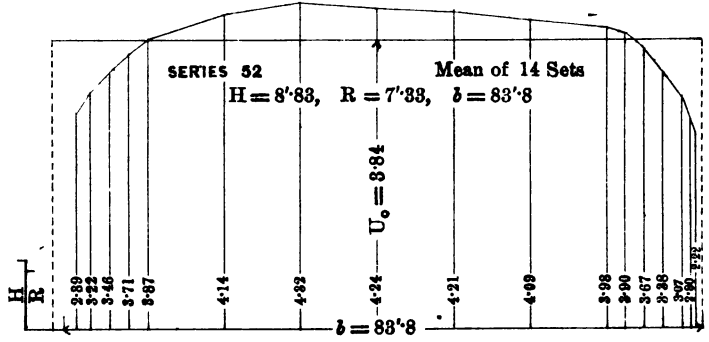
SURFACE VELOCITY CURVES.

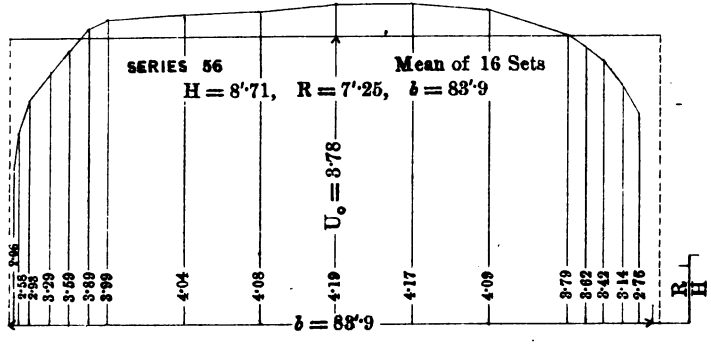
SOLANI AQUEDUCT

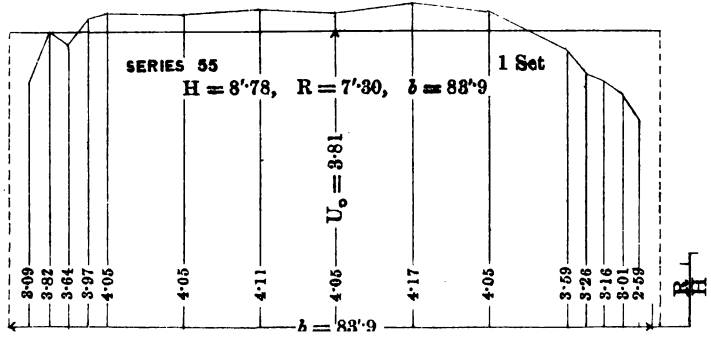
Scale for Cross-Section, and for Abscissæ, and for H, R, b, 25 feet to an inch.

Velocity-Scale, 2·5 feet per second to an inch.



[No Series in Left Aqueduct corresponding in depth to Series No. 55.





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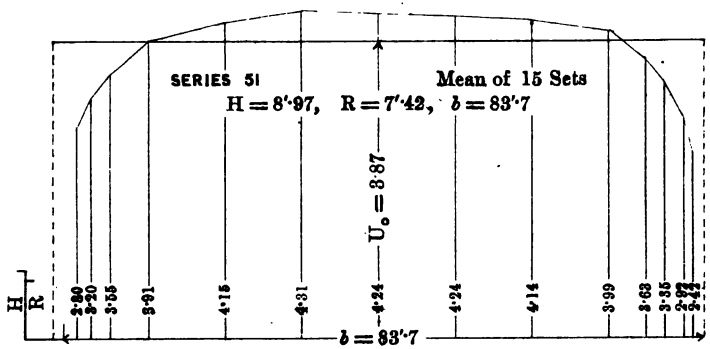
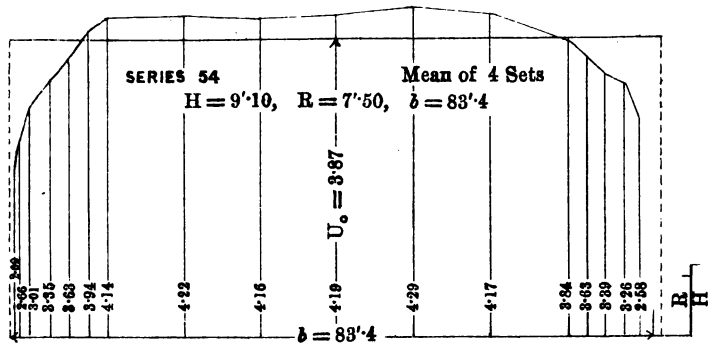
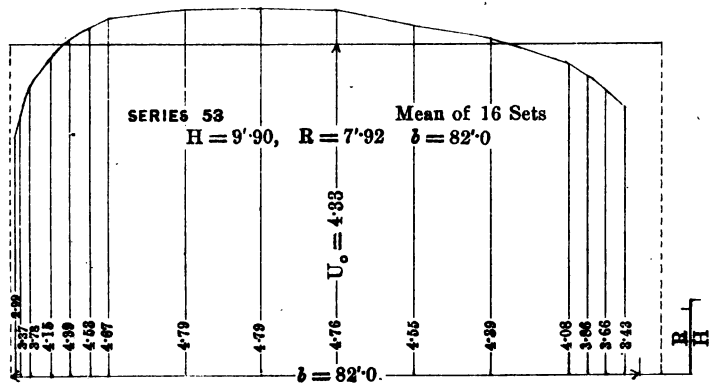
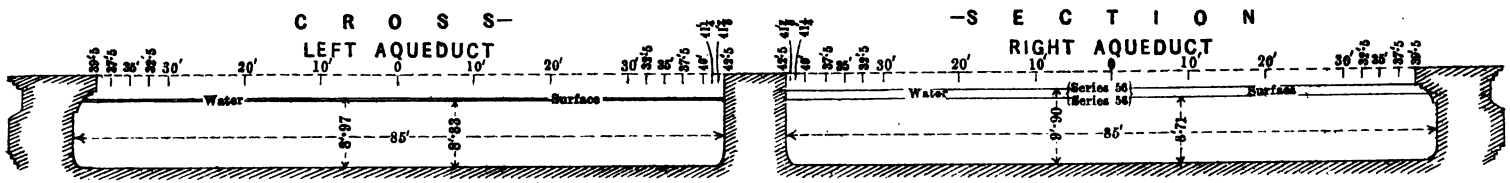






[No Series in Left Aqueduct corresponding in depth to Series No. 53].



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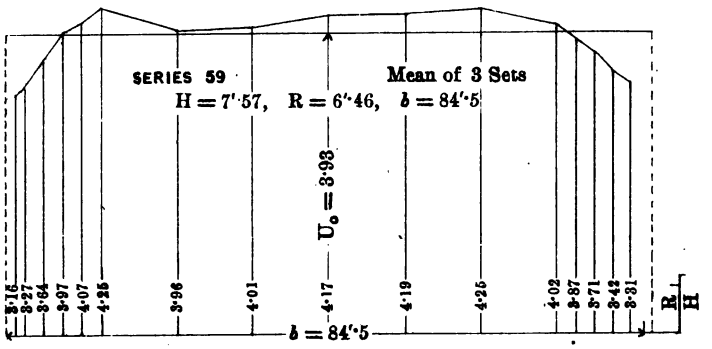
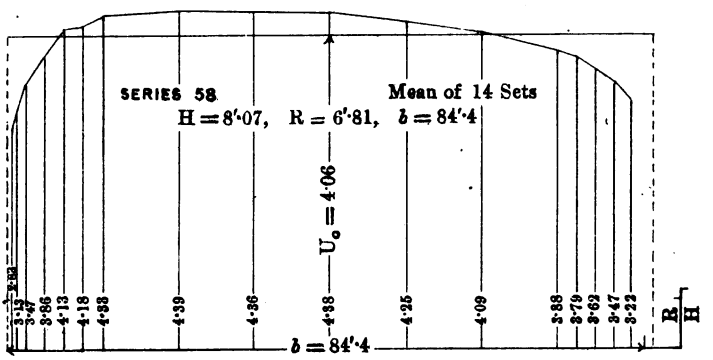
SURFACE VELOCITY CURVES.

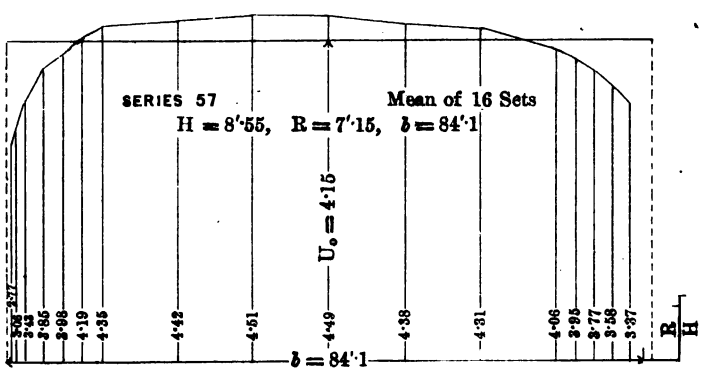
SOLANI RIGHT AQUEDUCT

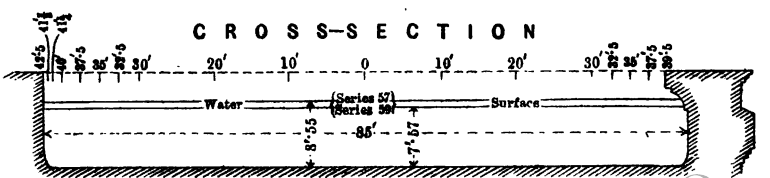
Scale for Cross-Section, and for Abscissæ, and for H, R, b, 25 feet to an inch.

Velocity-Scale, 2·5 feet per second to an inch.









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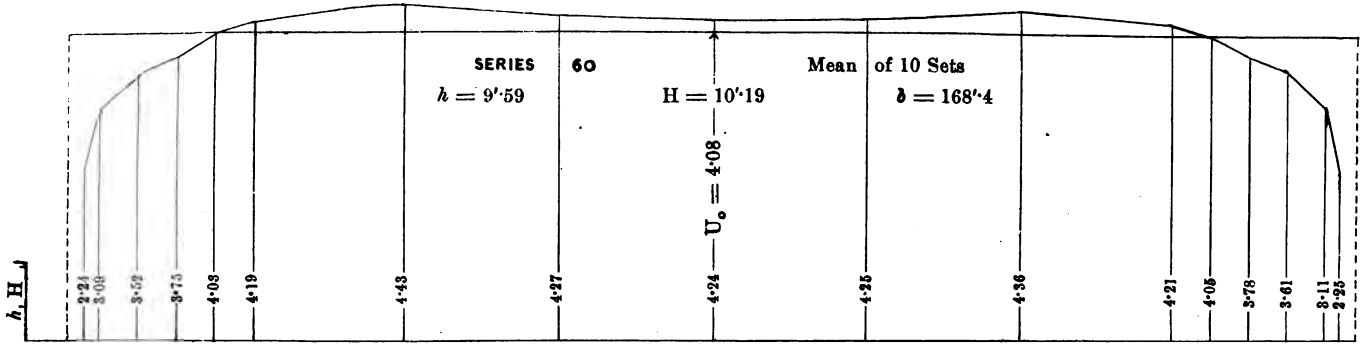
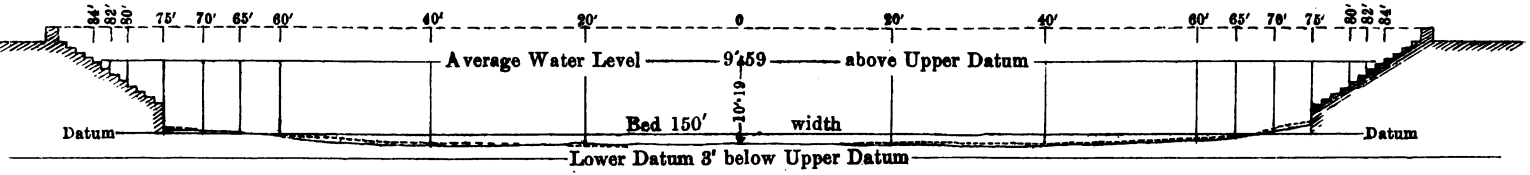
SURFACE VELOCITY CURVES.

SOLANI EMBANKMENT MINOR SITES

Scale for Cross-Section, and for Abscissæ, and for h, H, b, 25 feet to an inch.
Velocity-Scale, 2·5 feet per second to an inch.



CROSS-SECTION



| | | |

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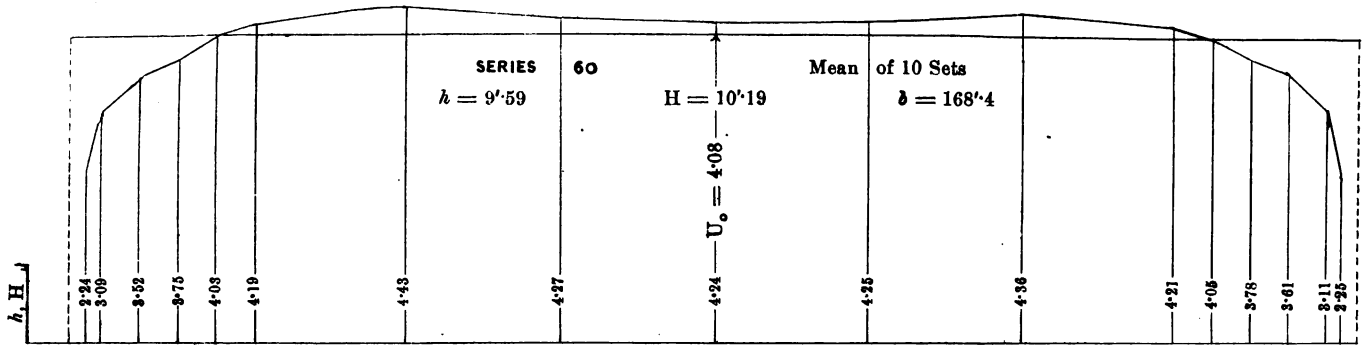
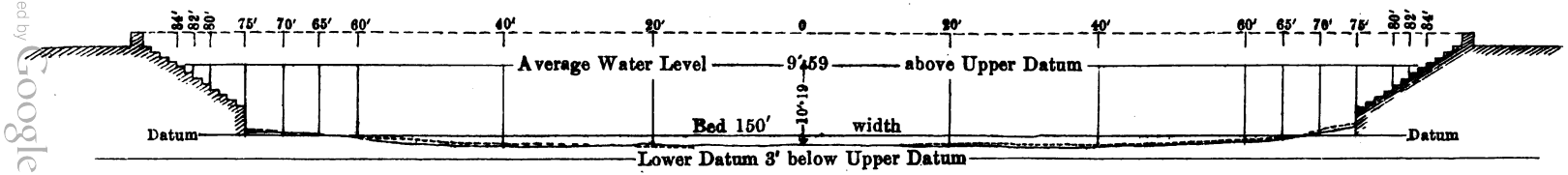
SURFACE VELOCITY CURVES.

SOLANI EMBANKMENT MINOR SITES

Scale for Cross-Section, and for Abscissæ, and for h, H, b, 25 feet to an inch.
Velocity-Scale, 2·5 feet per second to an inch.



CROSS-SECTION



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BED VELOCITY CURVES.

SOLANI RIGHT AQUEDUCT

[These are Curves of Velocities past a transversal a little above the Bed].

Scale for Cross-Section, and for Abscissæ, and for H, R, b, 25 *feet to an inch.*
Velocity-Scale, 2·5 *feet per second to an inch.*

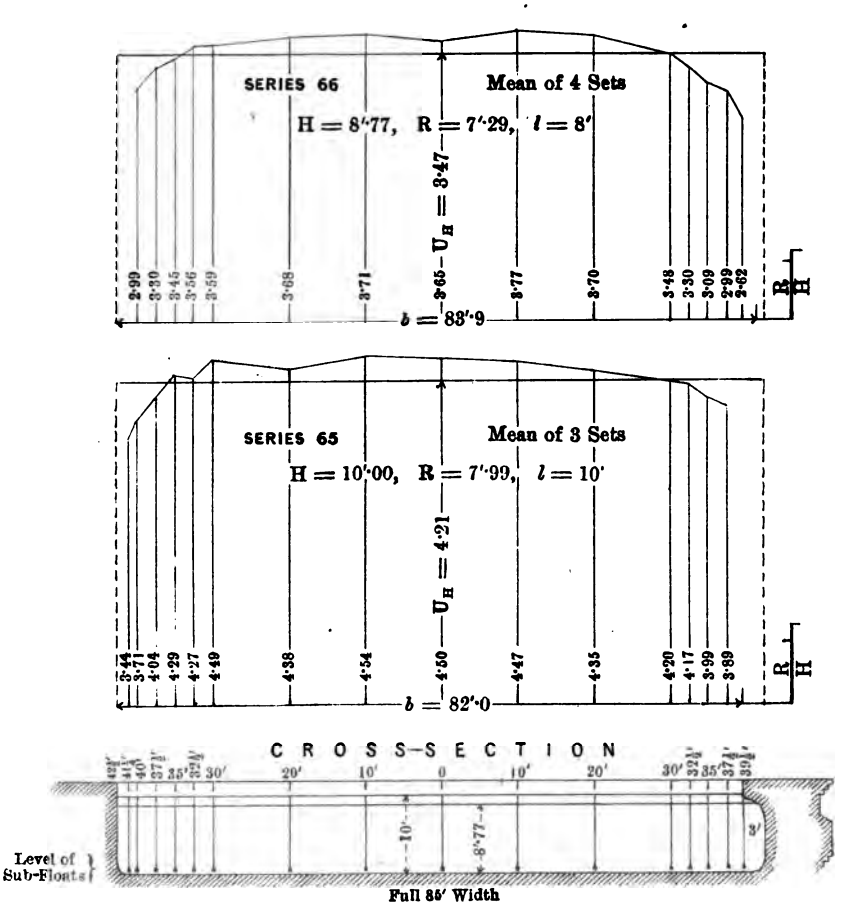

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PLATE XXIX.

MIDDEPTH VELOCITY CURVES.

SOLANI RIGHT AQUEDUCT

[These are Curves of Velocities past a transversal a little above middepth].

Scale for Cross-Section, and for Abscissæ, and for H, R, b, 25 feet to an inch.
Velocity-Scale, 2·5 feet per second to an inch.

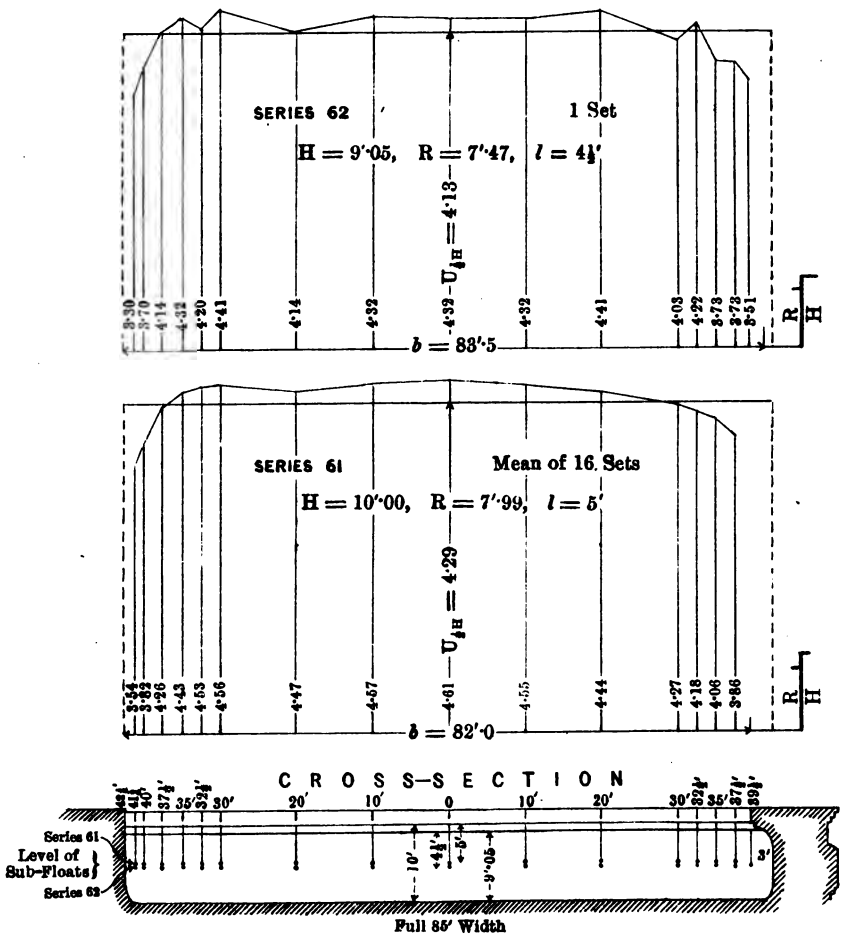

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PLATE XXX A.

TRANSVERSE VELOCITY CURVES.

SOLANI RIGHT AQUEDUCT

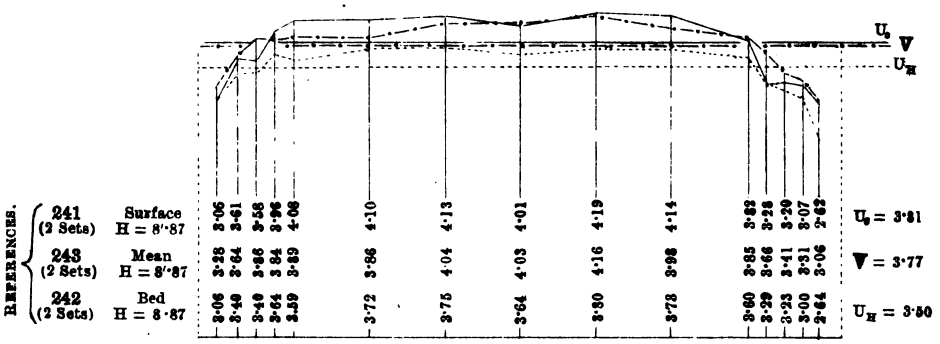
Scale for Cross-Sections, and for Abscissæ, 25 feet to an inch.

FIG. 3.

Velocity-Scale, 2·5 feet per second to an inch.

References { Surface Velocity Curve, and Mean Surface-Velocity Line
Bed Velocity Curve, and Mean Bed-Velocity Line.
Mean Velocity Curve, and Mean (Sectional) Velocity Line.

N.B. *These Curves are comparable in all respects; the Field work having been done in concert.*



CROSS-SECTION

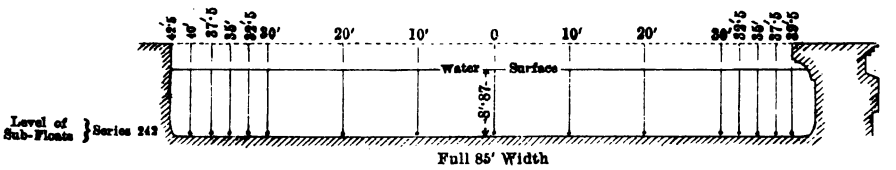
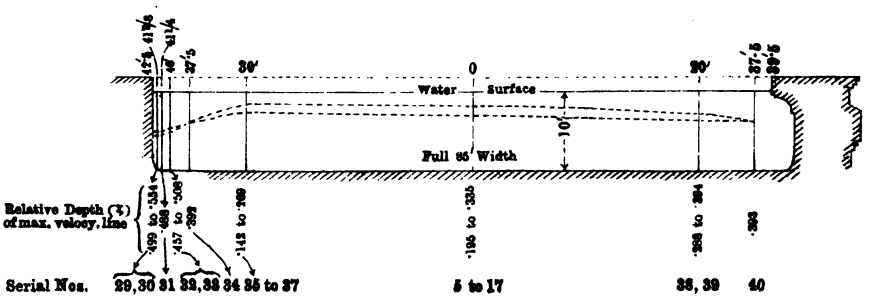


FIG. 4.

CROSS-SECTION

Showing relative depth of maximum velocity on different verticals.

[The dotted lines connect the points of maximum velocity on the several verticals].



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TRANSVERSE VELOCITY CURVES.

SOLANI RIGHT AQUEDUCT

Scale for Cross-Section, and for Abscissæ, 25 feet to an inch.

Velocity-Scale, 2·5 feet per second to an inch.

References { Surface Velocity Curves, and Mean Surface-Velocity Line.
Middepth Velocity Curves, and Mean Middepth-Velocity Line.
Bed Velocity Curves, and Mean Bed-Velocity Line.
Mean Velocity Curves, and Mean (Sectional) Velocity Line.

N.B. *The four Curves of either Figure are comparable as to shape only; not necessarily as to size, as they are the Results of Fieldwork done at different times.*

FIG. 1.

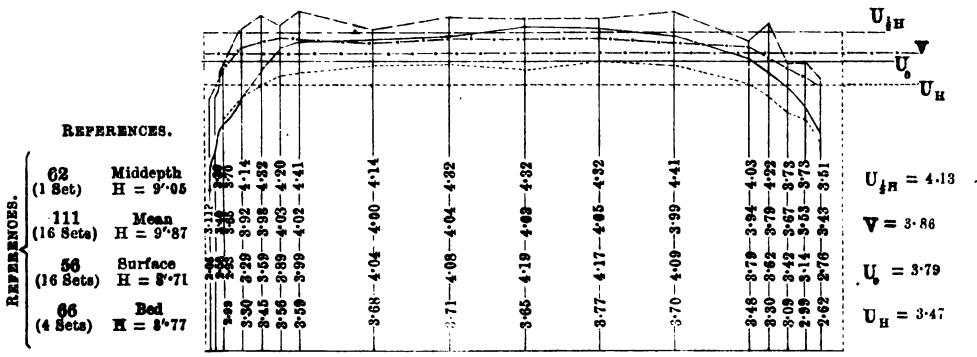
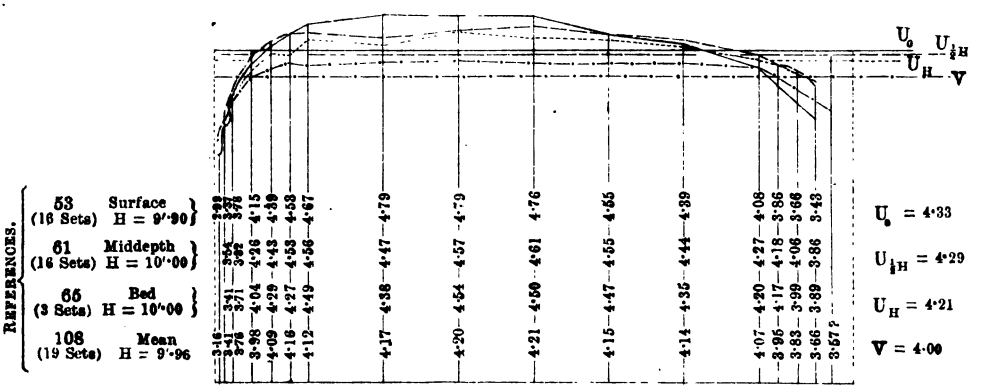
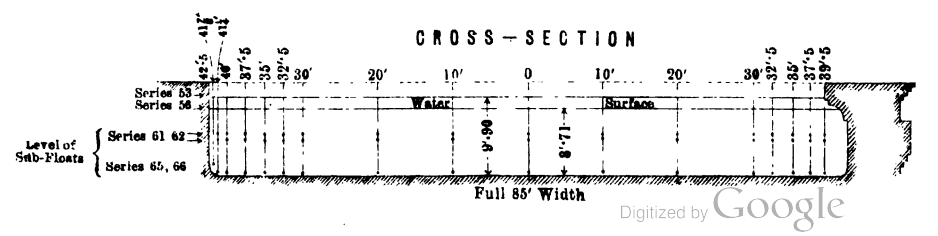

REFERENCES.
62 (1 Set) Middepth H = 9'·05
111 (16 Sets) Mean H = 9'·87
56 (16 Sets) Surface H = 8'·71
66 (4 Sets) Bed H = 8'·77
$U_{\frac{1}{2}H}$ = 4·13
V = 3·86
U_0 = 3·79
U_H = 3·47

FIG. 2.


REFERENCES.
53 (16 Sets) Surface H = 9'·90
61 (16 Sets) Middepth H = 10'·00
65 (3 Sets) Bed H = 10'·00
108 (19 Sets) Mean H = 9'·96
U_0 = 4·33
$U_{\frac{1}{2}H}$ = 4·29
U_H = 4·21
V = 4·00



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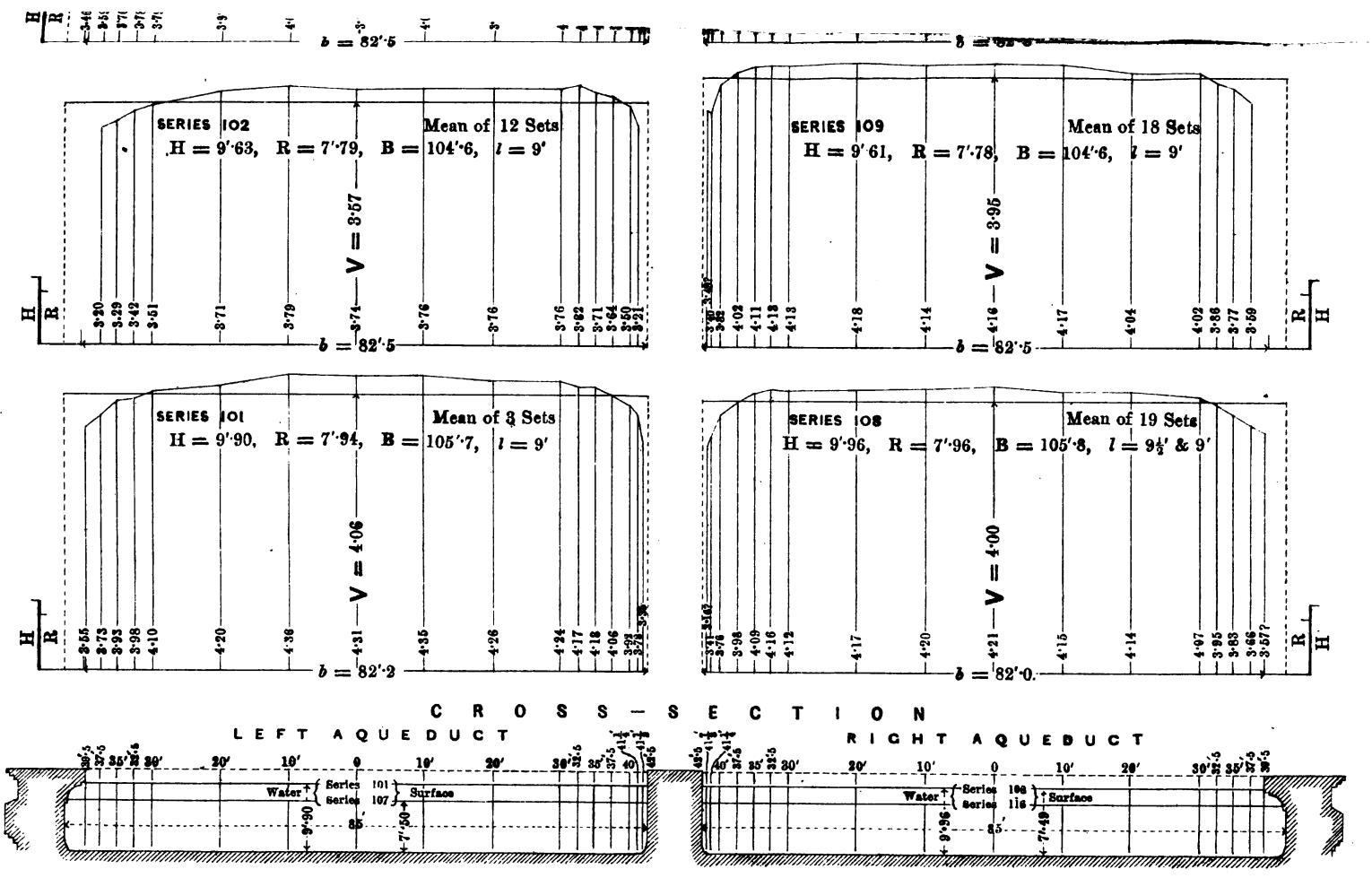

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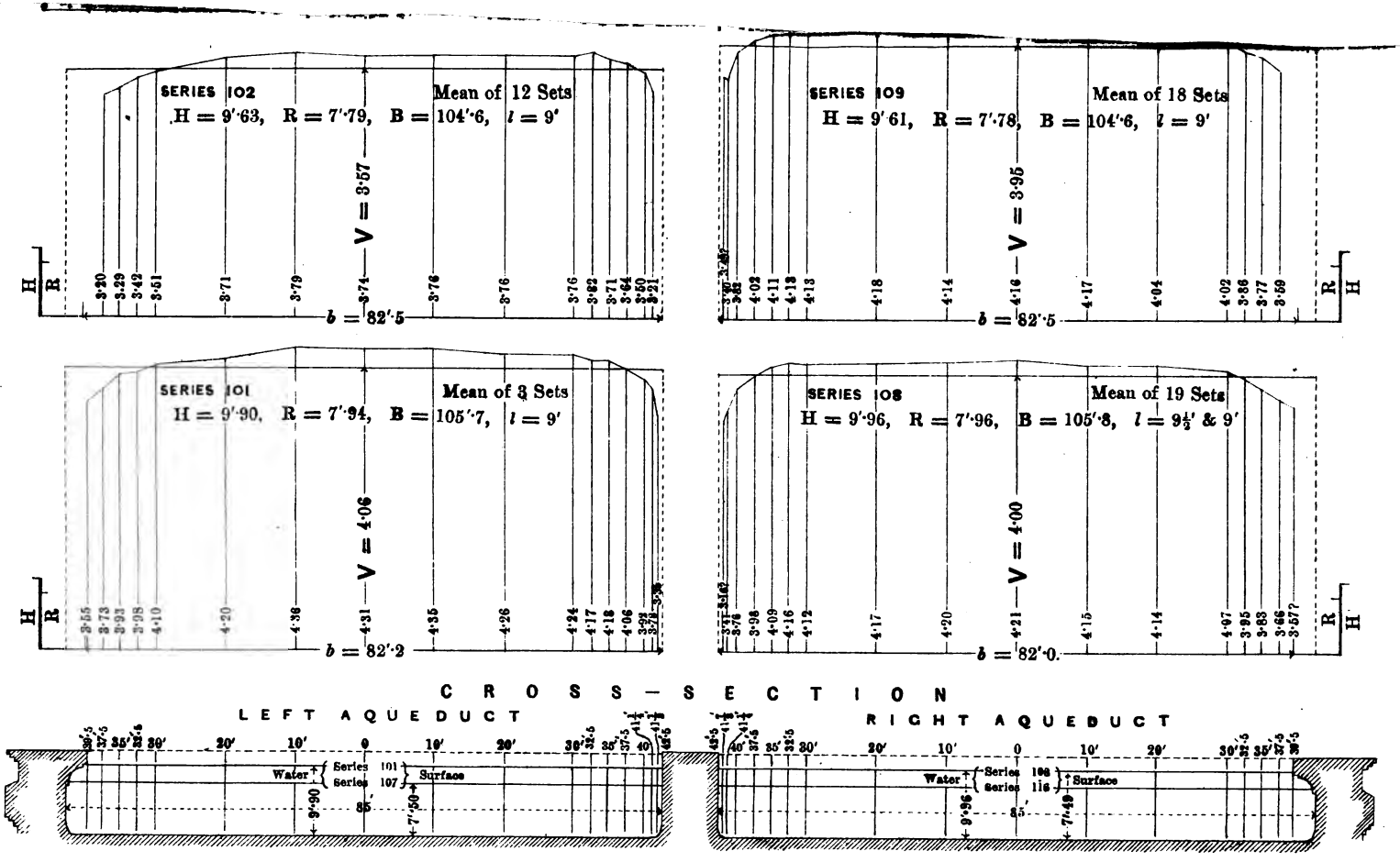

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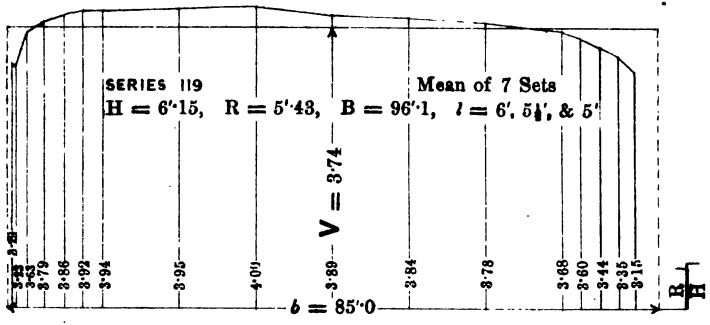
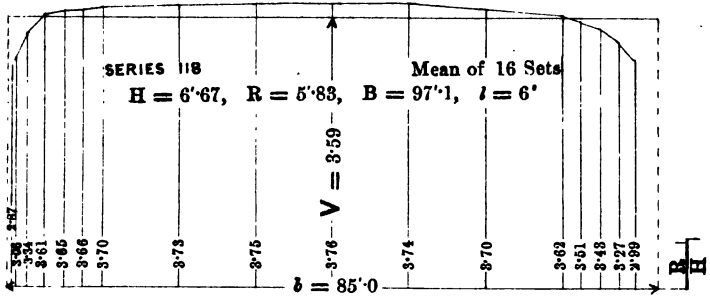
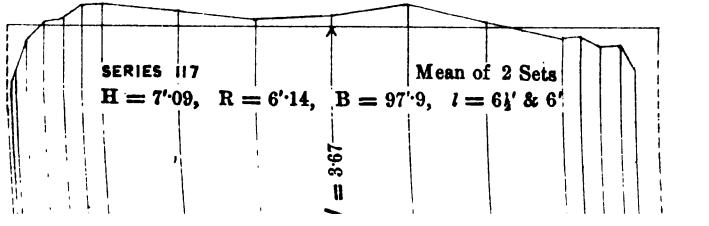
MEAN VELOCITY CURVES.

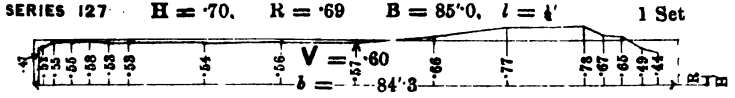
SOLANI RIGHT AQUEDUCT

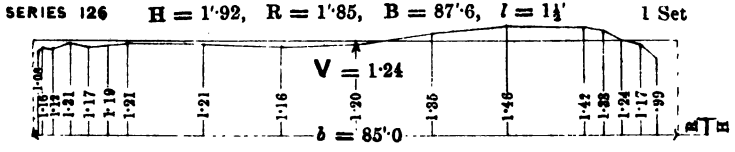


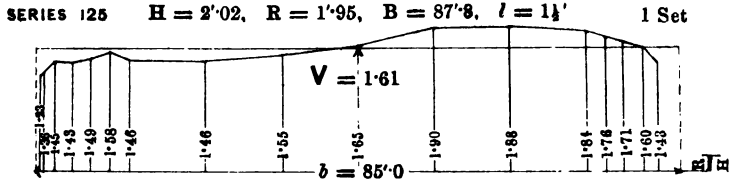


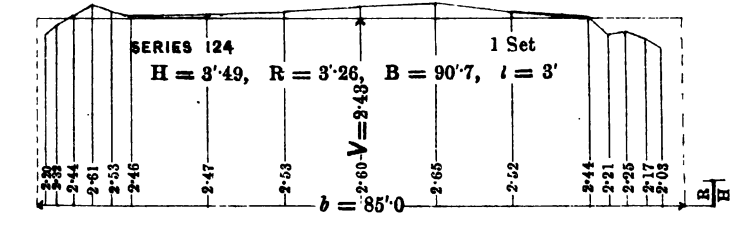


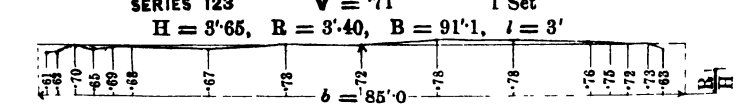
Velocity-Scale, 2·5 feet per second to an inch.











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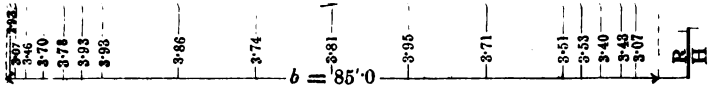
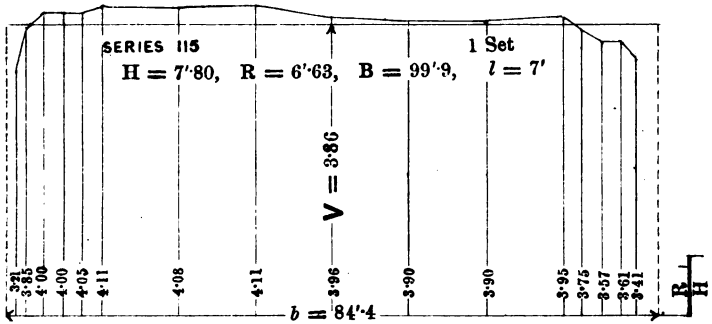
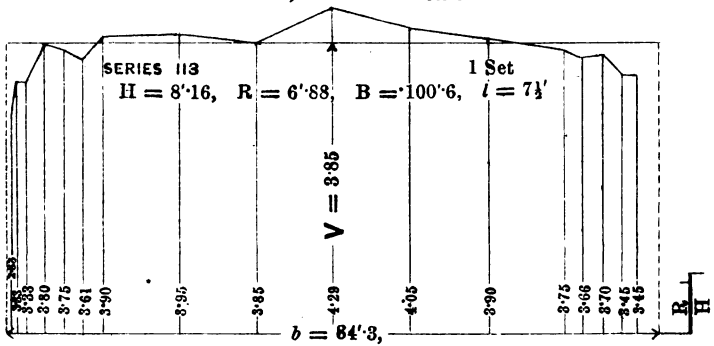
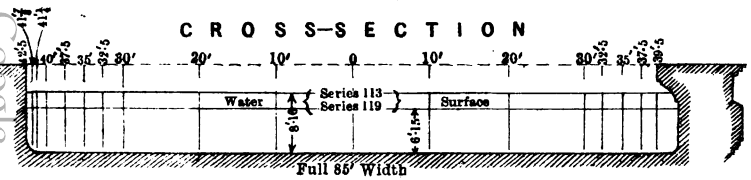


SERIES 116, SEE PLATE XXXI

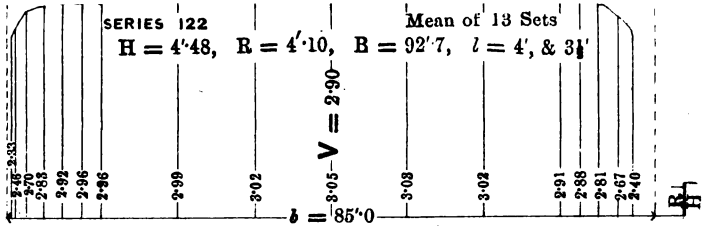


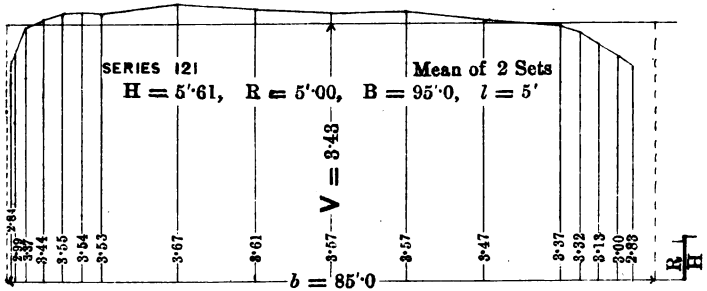
SERIES 114, SEE PLATE XXXI

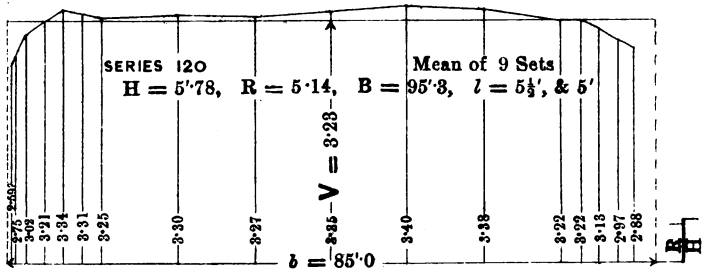


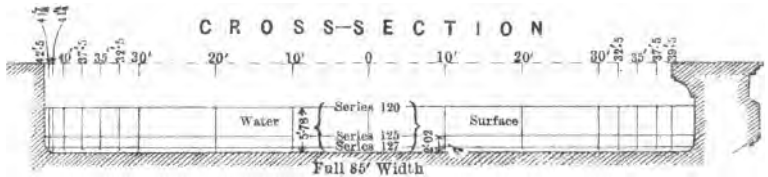


Scale for Cross-Section, and for Abscissæ, and for H, R, b, 25 feet to an inch.









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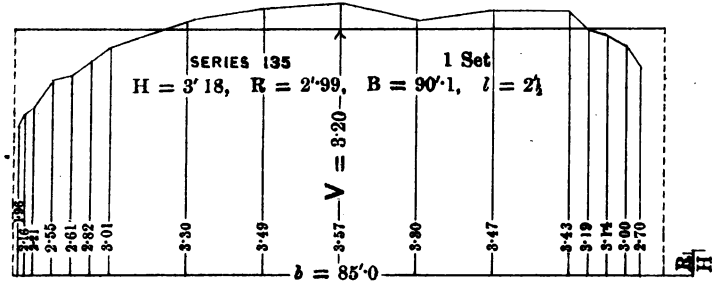
MEAN VELOCITY CURVES.

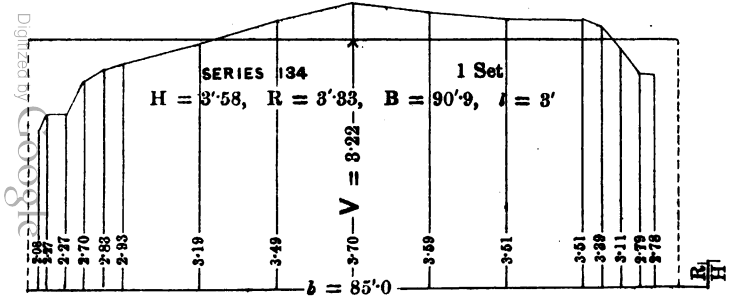
SOLANI RIGHT AQUEDUCT

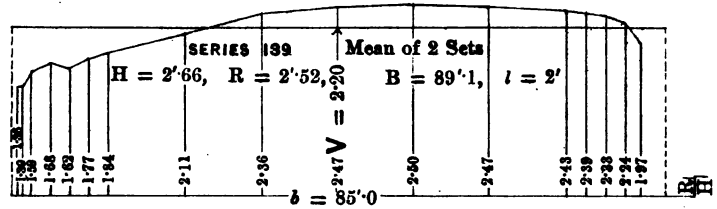
[LEFT AQUEDUCT CLOSED]

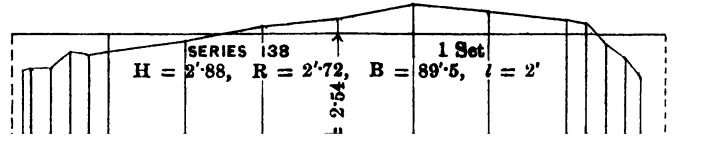
Scale for Cross-Section, and for Abscissæ, and for H, R, b, 25 feet to an inch.

Velocity-Scale, 2·5 feet per second to an inch.

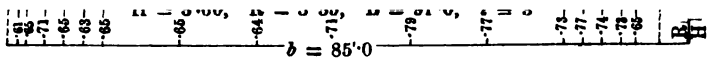


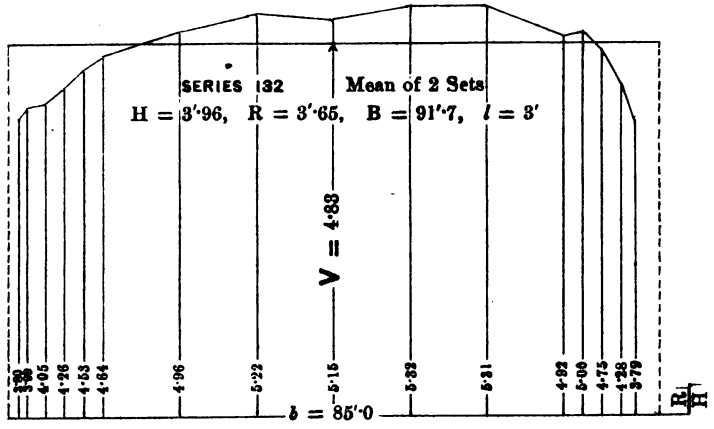


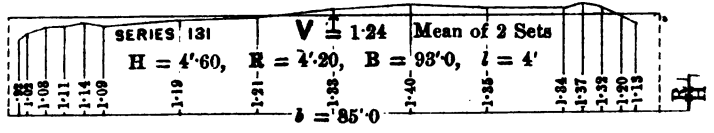


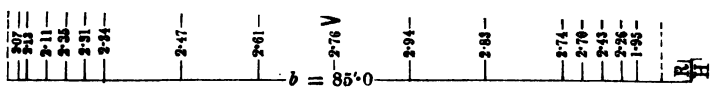


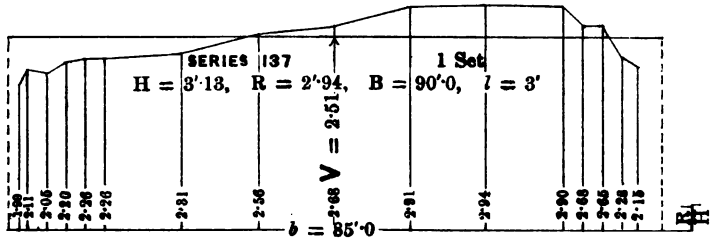
SERIES 133 V = ·69 1 Set

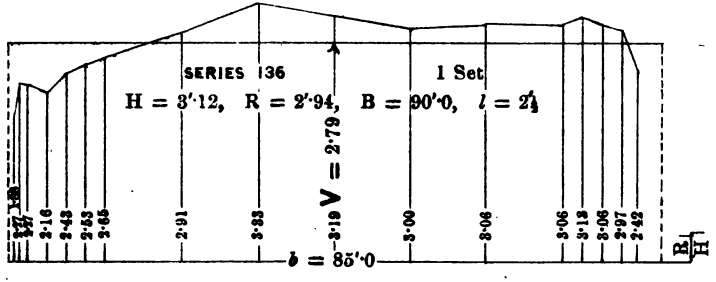

b = 85'·0

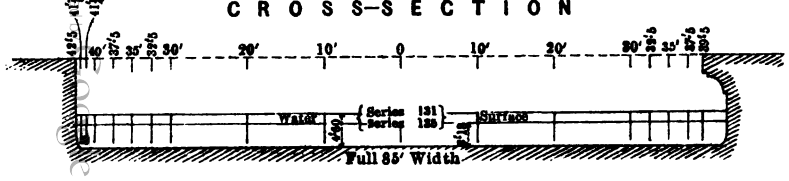

SERIES 132
Mean of 2 Sets
H = 3'·96, R = 3'·65, B = 91'·7, l = 3'
V = 4·83
b = 85'·0

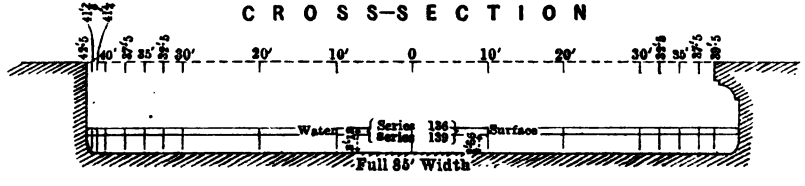

SERIES 131
V = 1·24
Mean of 2 Sets
H = 4'·60, R = 4'·20, B = 93'·0, l = 4'
b = 85'·0


b = 85'·0


SERIES 137
1 Set
H = 3'·13, R = 2'·94, B = 90'·0, l = 3'
V = 2·51
b = 85'·0


SERIES 136
1 Set
H = 3'·12, R = 2'·94, B = 90'·0, l = 2½'
V = 2·79
b = 85'·0


CROSS-SECTION
Water
Series 131
Series 135
Surface
Full 85' Width


CROSS-SECTION
Water
Series 136
Series 139
Surface
Full 85' Width

Digitized by Google

(13-11-78).

line

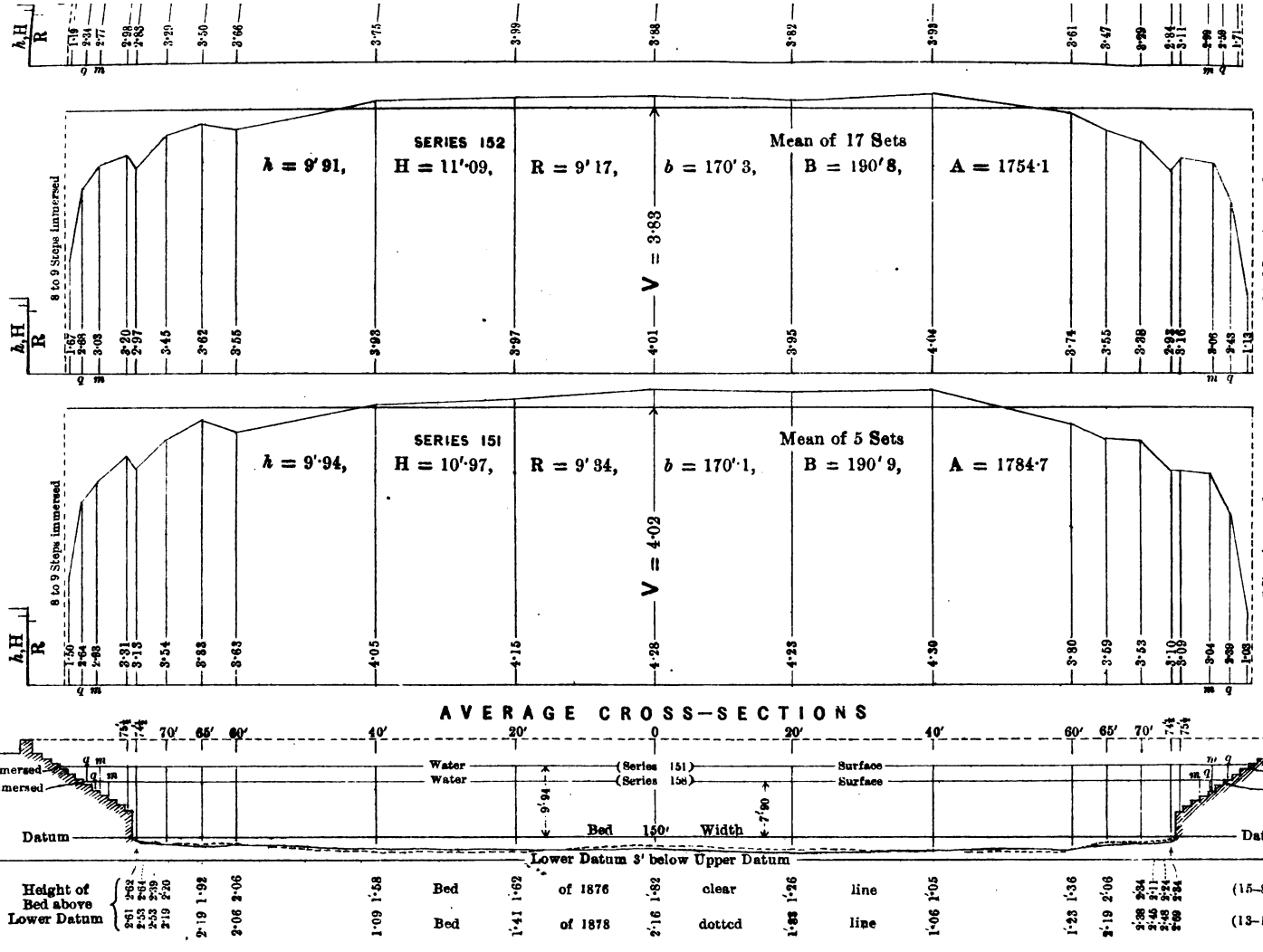
dotted

of 1878

Red

Digitized by Google

Digitized by Google


SERIES 152
h = 9'91, H = 11'09, R = 9'17, b = 170'3, B = 190'8, A = 1754·1
Mean of 17 Sets
V = 3·83
8 to 9 Steps immersed
SERIES 151
h = 9'94, H = 10'97, R = 9'34, b = 170'1, B = 190'9, A = 1784·7
Mean of 5 Sets
V = 4·02
9 Steps immersed
AVERAGE CROSS—SECTIONS
8 to 9 steps immersed
6 steps immersed
Water (Series 151) Surface
Water (Series 158) Surface
9'94
7'90
Bed 150' Width
Datum
Lower Datum 3' below Upper Datum
Height of Bed above Lower Datum
Bed of 1876 clear line (15–8–76).
Bed of 1878 dotted line (13–11–78).

Scale for Cross-Section,

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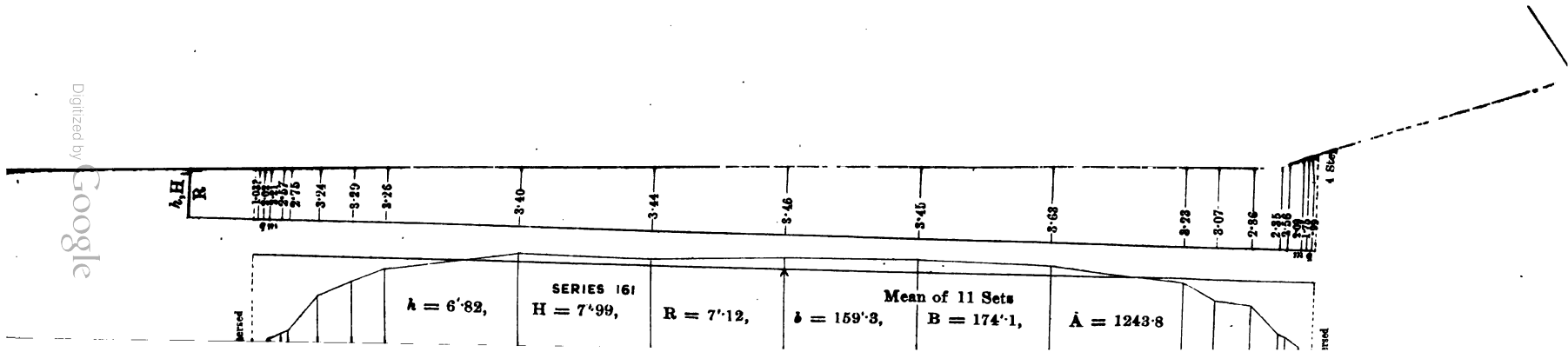
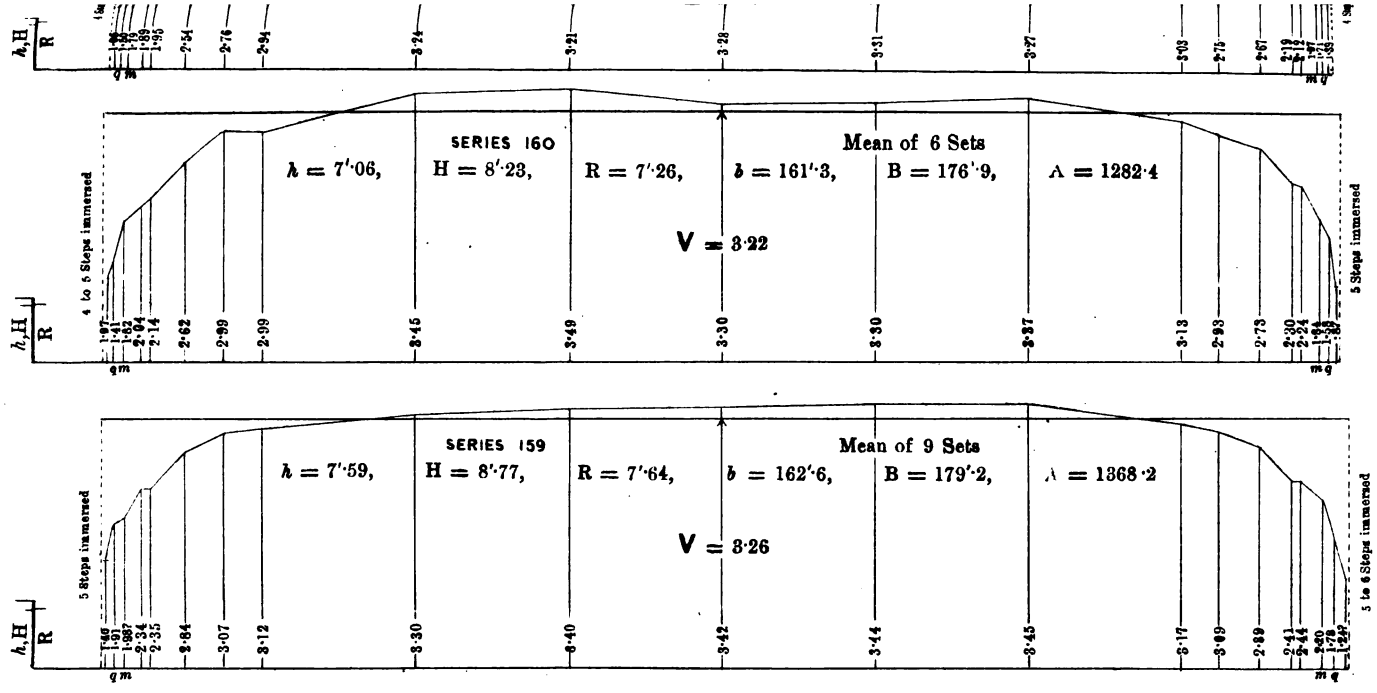
Digitized by Google

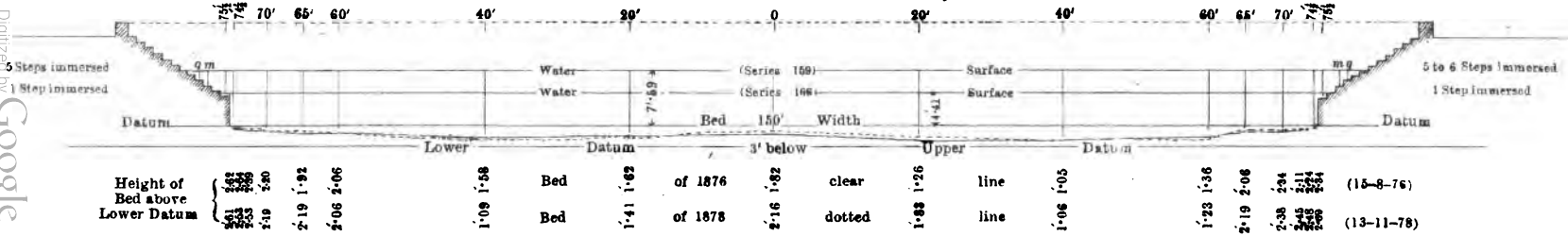
Digitized by Google



Digitized by Google


SERIES 160
Mean of 6 Sets
h = 7′·06, H = 8′·23, R = 7′·26, b = 161′·3, B = 176′·9, A = 1282·4
V = 3·22
4 to 5 Steps immersed
5 Steps immersed
SERIES 159
Mean of 9 Sets
h = 7′·59, H = 8′·77, R = 7′·64, b = 162′·6, B = 179′·2, A = 1368·2
V = 3·26
5 Steps immersed
5 to 6 Steps immersed
h,H
R
q m
m q

AVERAGE CROSS-SECTIONS



Height of Bed above Lower Datum	2·62 2·53 2·19	1·92	2·06	1·09	1·58	Bed	1·41	1·62	of 1876	2·16	1·82	clear	1·68	1·26	line	1·06	1·05	1·23	1·36	2·19	2·06	2·38	2·34	2·45	2·41	2·60	2·64	(15–8–76)
	2·61 2·53 2·19	1·92	2·06	1·09	1·58	Bed	1·41	1·62	of 1878	2·16	1·82	dotted	1·68	1·26	line	1·06	1·05	1·23	1·36	2·19	2·06	2·38	2·34	2·45	2·41	2·60	2·64	(13–11–78)

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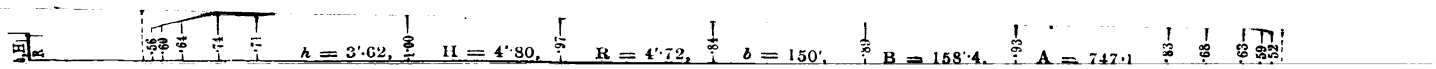
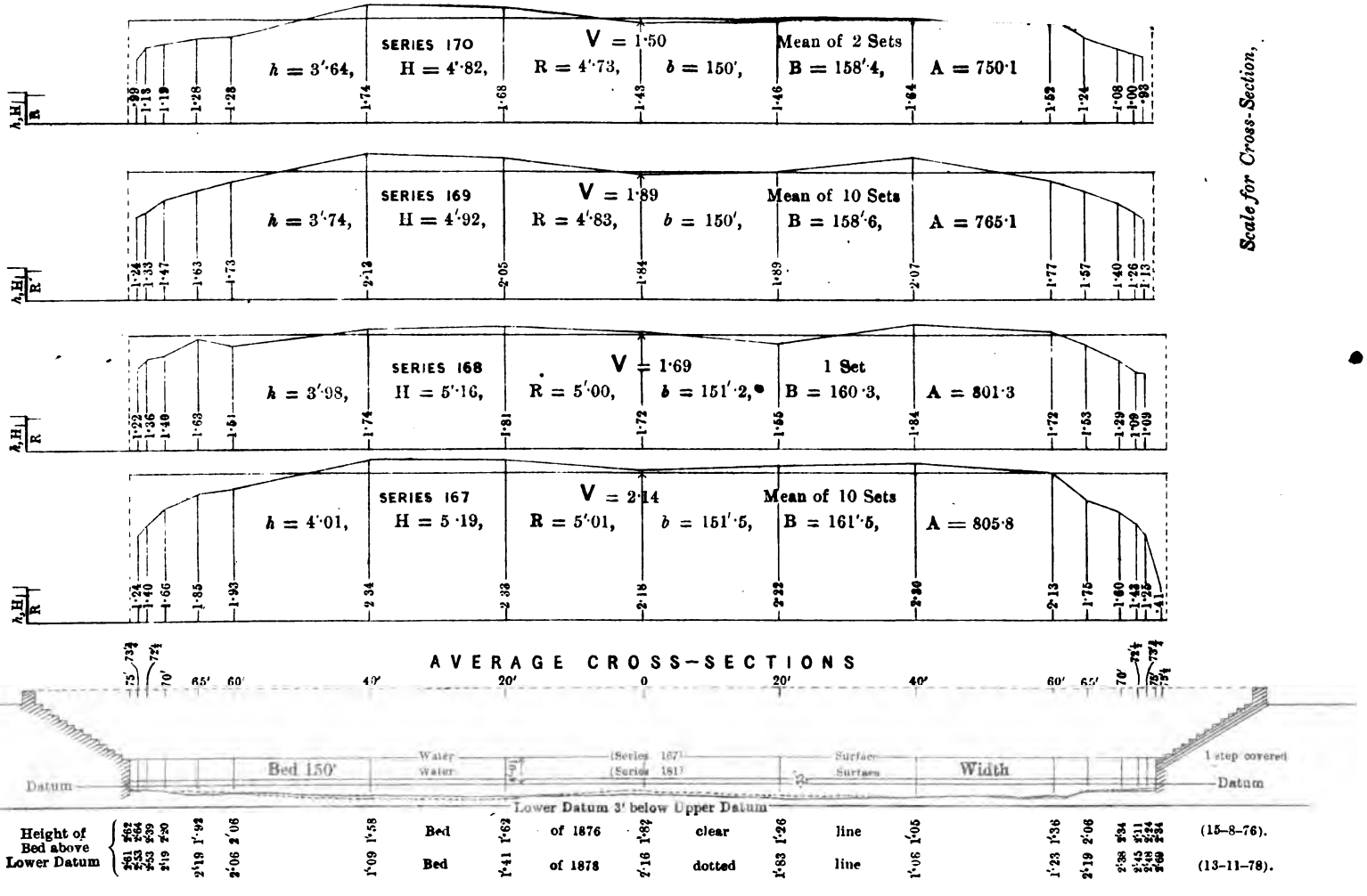


Digitized by Google



Scale for Cross-Section,

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Digitized by Google

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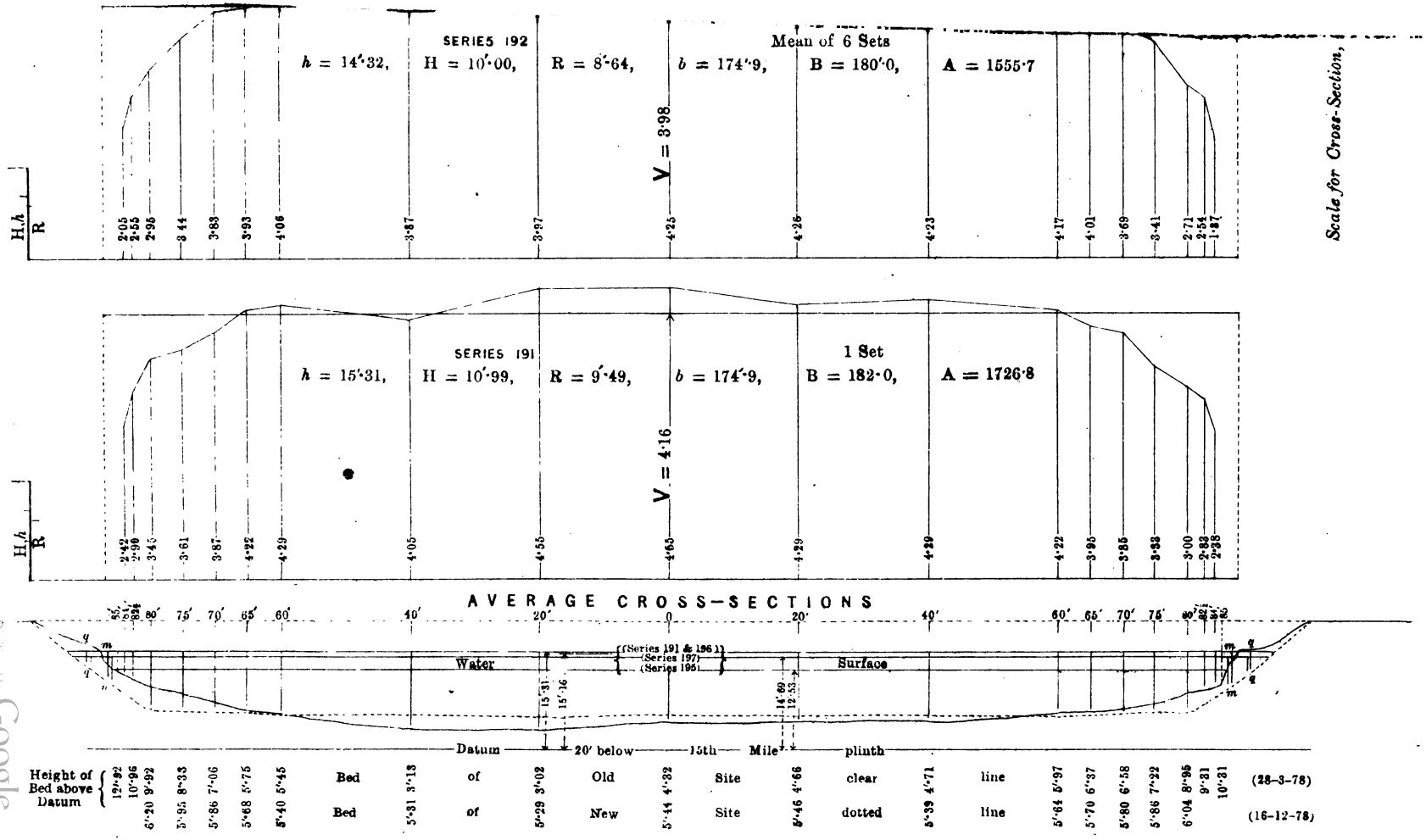
Digitized by Google



Scale for Cross-Section,

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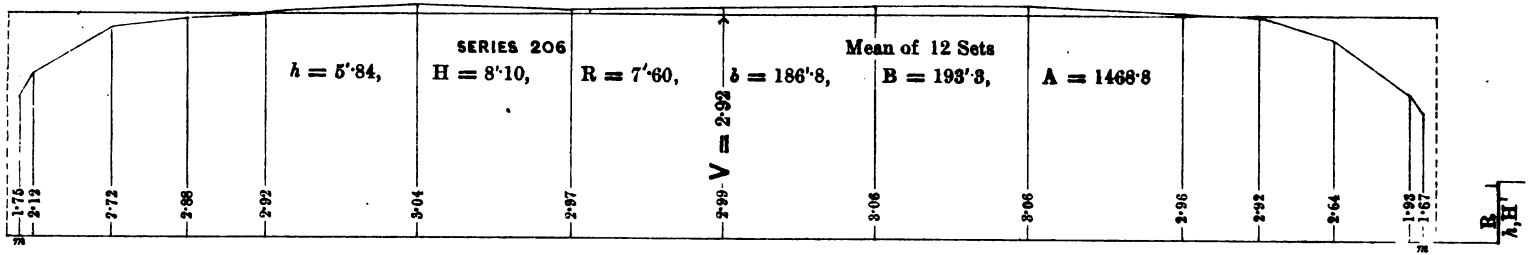
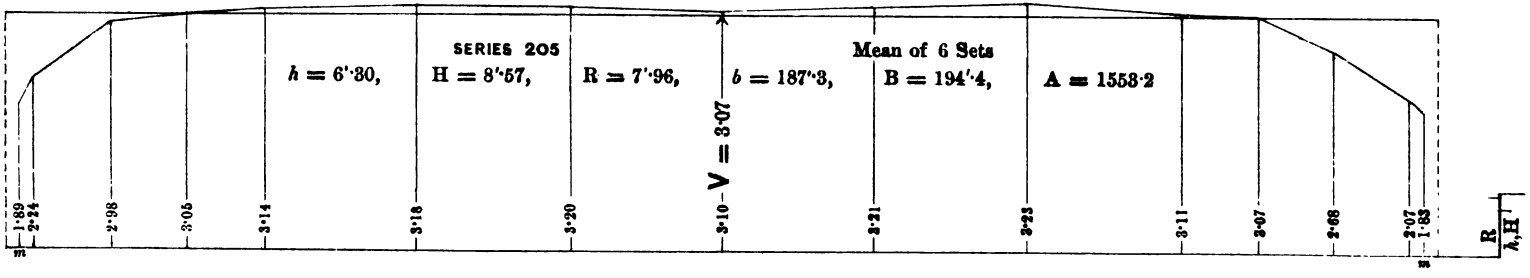
Digitized by Google

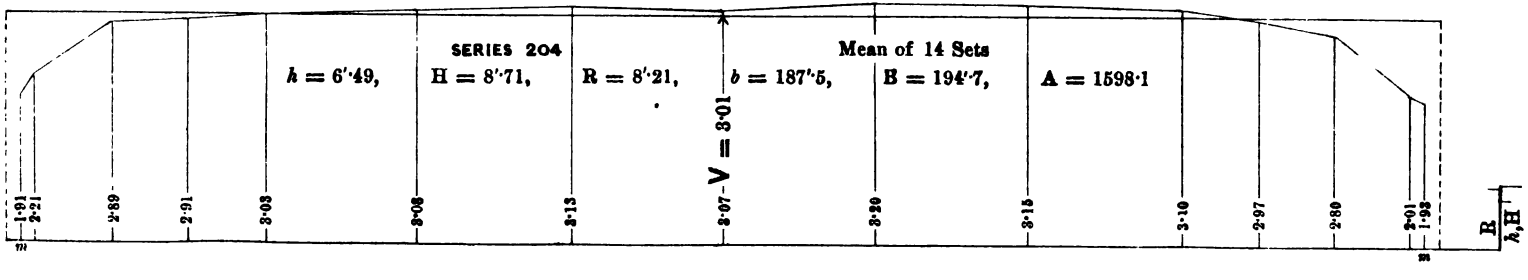
Digitized by Google

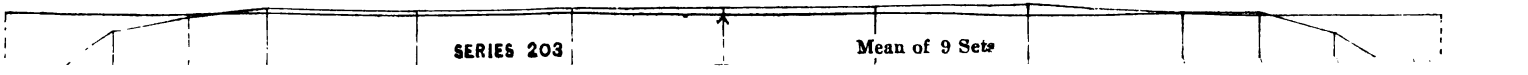
MEAN VELOCITY CURVES.

BELRA SITE









2, b, 25 feet to an inch. Velocity-Scale, 2·5 feet per second to an inch.

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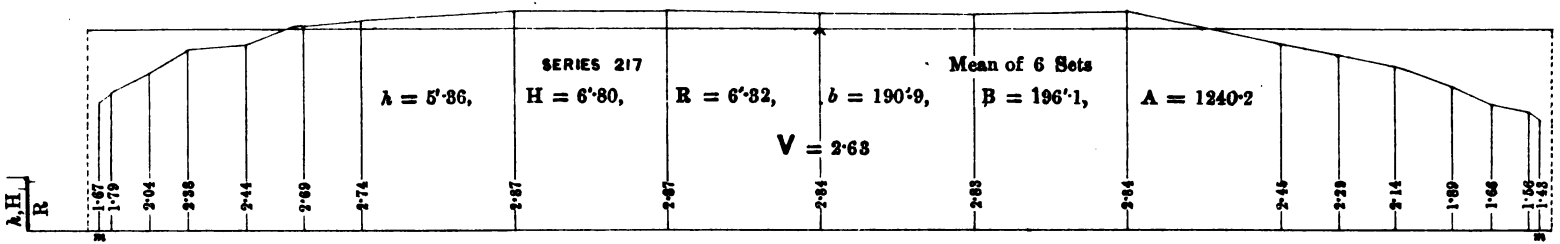
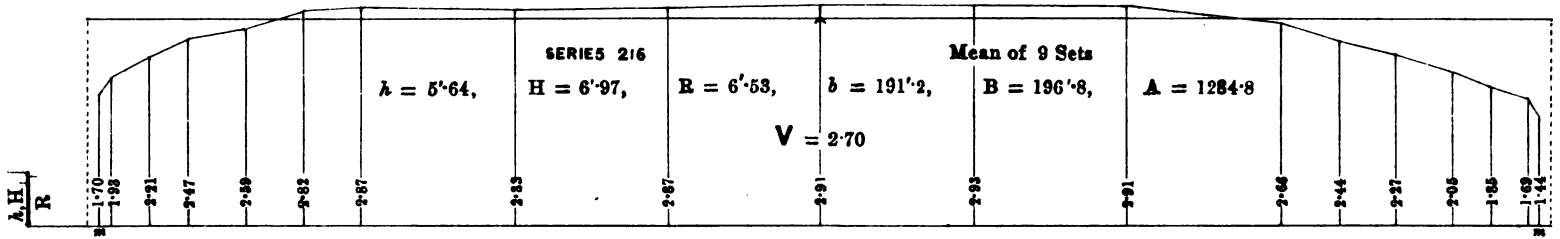
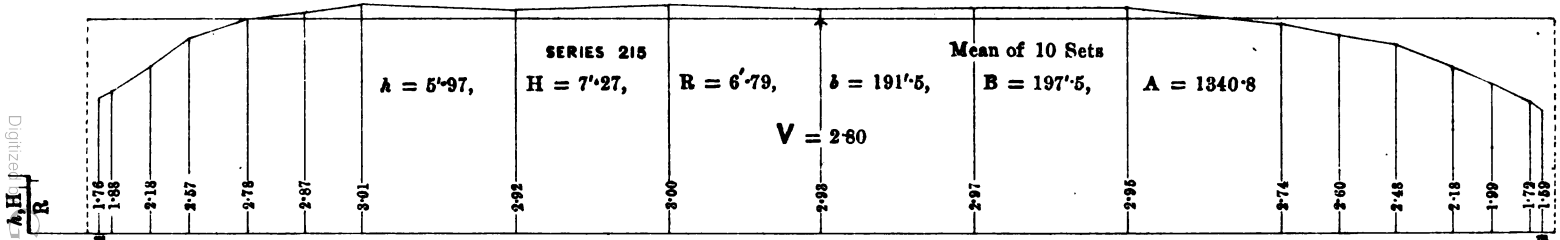
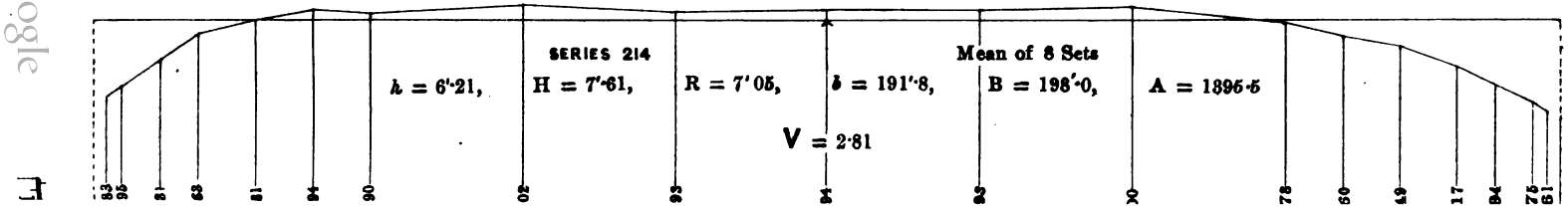
MEAN VELOCITY CURVES.

JAOLI SITE





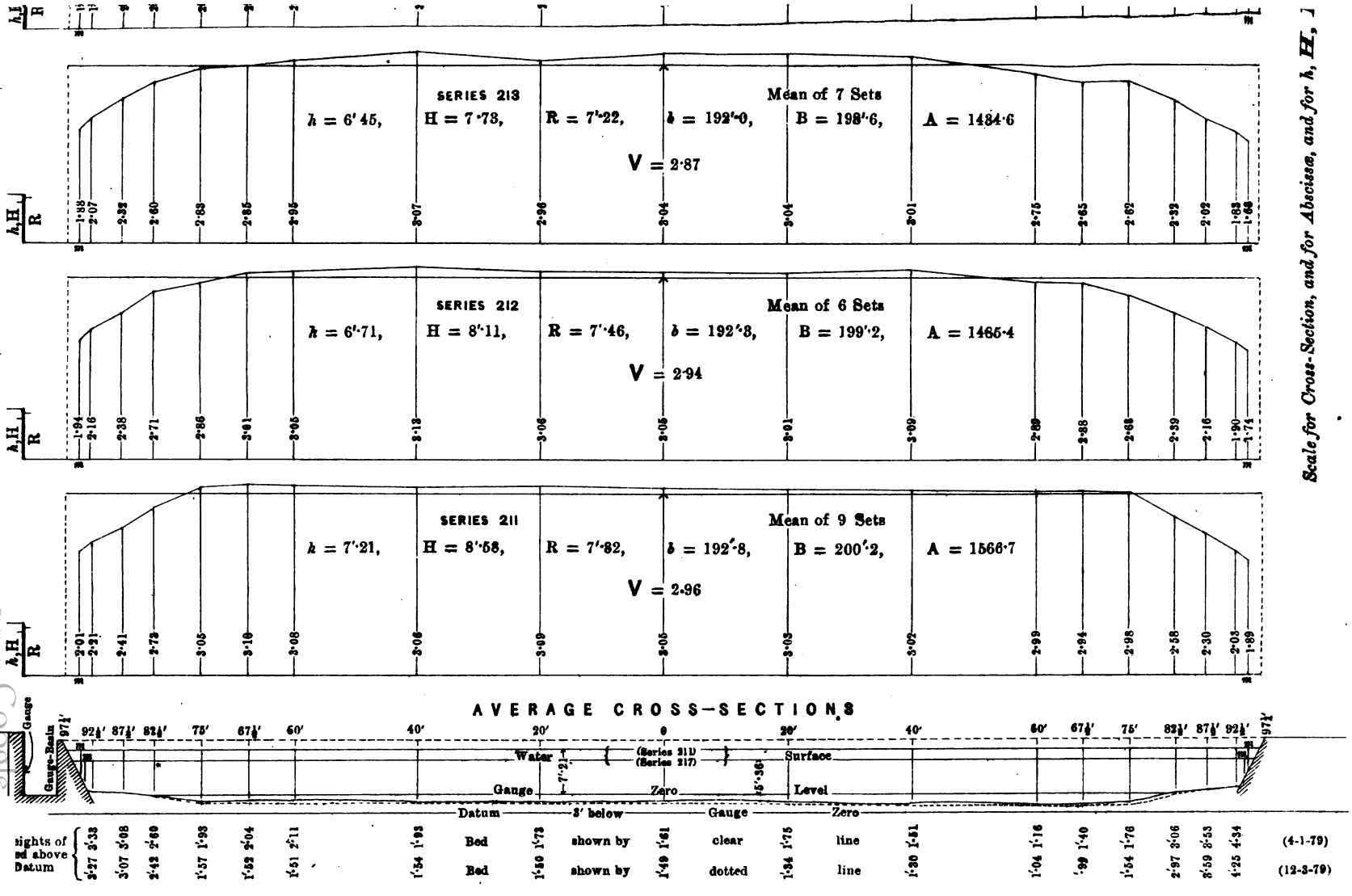




Velocity-Scale, 2·5 feet per second to an inch.

" 25 feet to an inch.

Digitized by Google


SERIES 213
Mean of 7 Sets
h = 6'45, H = 7'73, R = 7'22, b = 192'0, B = 198'6, A = 1484·6
V = 2·87
1·88 2·07 2·32 2·60 2·83 2·85 2·95 3·07 2·96 3·04 3·04 3·01 2·75 2·65 2·62 2·32 2·02 1·85 1·68
SERIES 212
Mean of 6 Sets
h = 6'71, H = 8'11, R = 7'46, b = 192'8, B = 199'2, A = 1465·4
V = 2·94
1·94 2·16 2·38 2·71 2·86 3·01 3·05 3·13 3·06 3·05 3·01 3·00 2·89 2·88 2·68 2·39 2·16 1·90 1·74
SERIES 211
Mean of 9 Sets
h = 7'21, H = 8'58, R = 7'82, b = 192'8, B = 200'2, A = 1566·7
V = 2·96
2·01 2·21 2·41 2·73 3·05 3·10 3·08 3·06 3·09 3·05 3·03 3·02 2·99 2·94 2·95 2·58 2·30 2·03 1·89
AVERAGE CROSS-SECTIONS
Gauge
Gauge-Basin
92½' 87½' 82½' 75' 67½' 60' 40' 20' 0 20' 40' 60' 67½' 75' 82½' 87½' 92½'
Water Surface
(Series 211)
(Series 217)
7'·21
45'·36
Gauge Zero Level
Datum 3' below Gauge Zero
Bed shown by clear line
Bed shown by dotted line
(4-1-79)
(12-3-79)
Scale for Cross-Section, and for Abscissæ, and for h, H,

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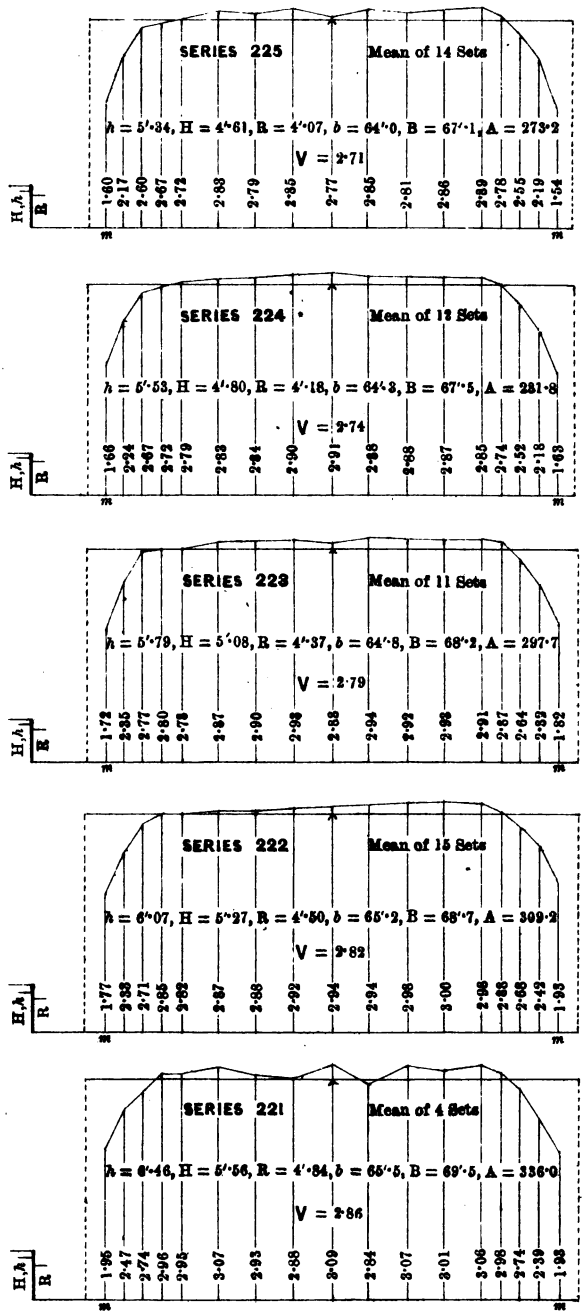
MEAN VELOCITY CURVES.

KAMHERA SITE



Scale for Cross-Section, and for Abcissæ, and for h, H, R, b, 25 feet to an inch.

Velocity-Scale, 2·5 feet per second to an inch.

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MEAN VELOCITY CURVES.

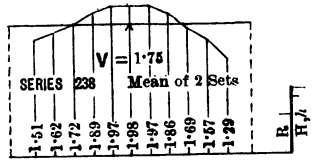
BELRA REACH DISTRIBUTARIES

PLATE XLI.

PIMORA DISTRIBUTARY

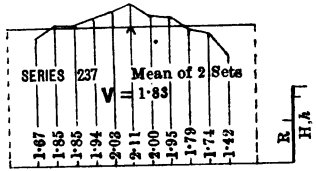
(leads out from left bank)

The Gauge is on the Right Bank, 143' *below the Expl. Site.*



$b = 12'·5$, B = 14'·8, A = 28·6

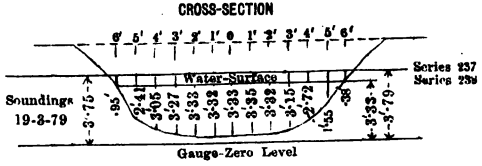
$h = 3'·33$, H = 2'·91, R = 1'·94



$b = 13'·0$, B = 16'·0, A = 34·5

$h = 3'·79$, H = 3'·37, R = 2'·16

CROSS-SECTION



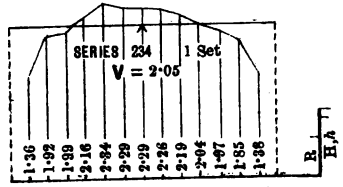
Velocity-Scale, 2·5 feet per second to an inch.

Scale of Depths, 10 feet to an inch.

MANSURPUR DISTRIBUTARY

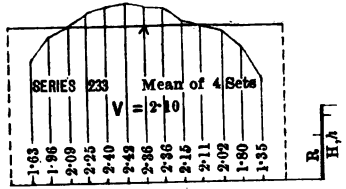
(leads out from right bank)

The Gauge is on the Right Bank, 50' *below the Expl. Site.*



$b = 13'·8$, B = 16'·9, A = 35·5

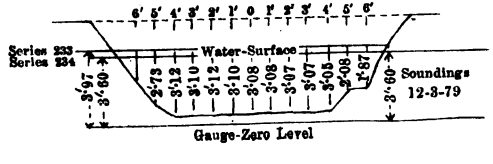
$h = 3'·60$, H = 3'·08, R = 2'·10



$b = 14'·1$, B = 17'·7, A = 41·0

$h = 3'·97$, H = 3'·48, R = 2'·32

CROSS-SECTION



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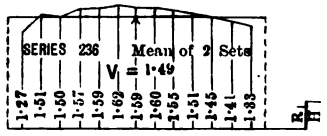
MIRANPUR DISTRIBUTARY

(leads out from left bank)

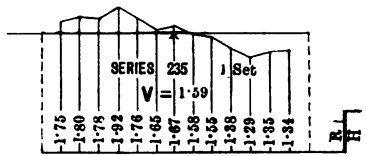
No permanent Gauge near this Site.



b = 13′·5, B = 14′·6, A = 17·0

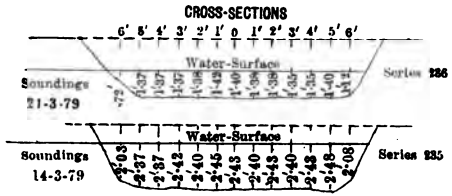
H = 1′·40, R = 1′·16

N.B —The Water-Level fell·70 during progress of Series 235



b = 13′·5, B = 14′·6, A = 17·0

H = 2′ 08, R = 1′·63

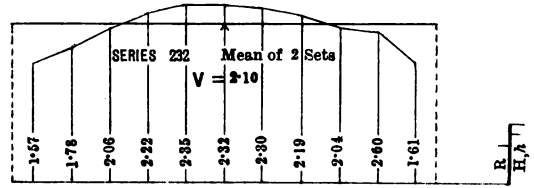


Scale for Cross-Sections, and for Abscissæ, and for h, H, R, b,

RIGHT JAOLI DISTRIBUTARY

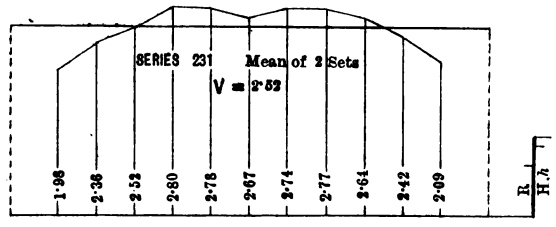
(leads out from right bank)

The Gauge is on the Right Bank, 100′ below the Expl. Site.



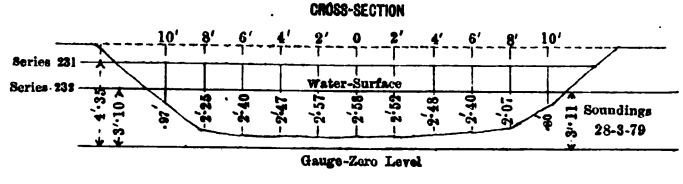
b = 22′·0, B = 23′·4, A = 46·5

h = 3′·10, H = 2′·57, R = 1′·99



b = 25′·0, B = 27′·2, A = 75·9

h = 4′·35, H = 3′·82, R = 2′·79



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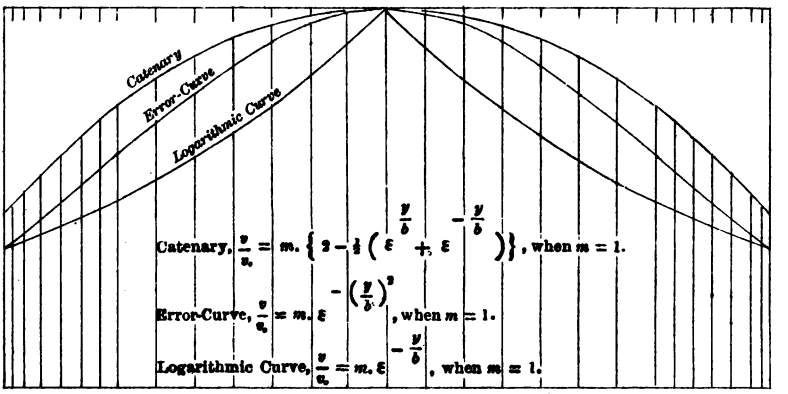
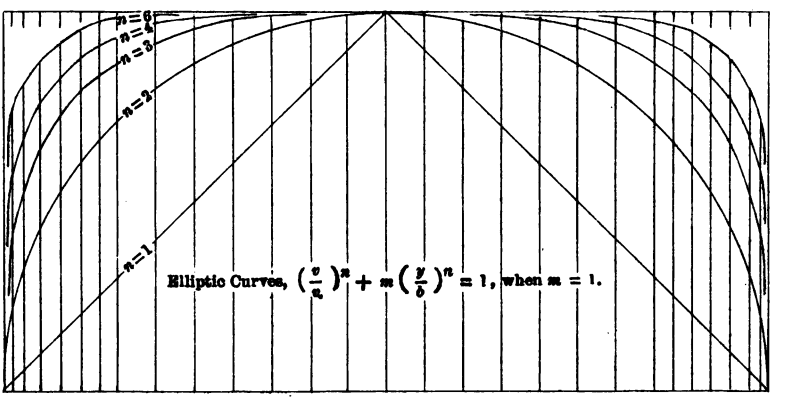
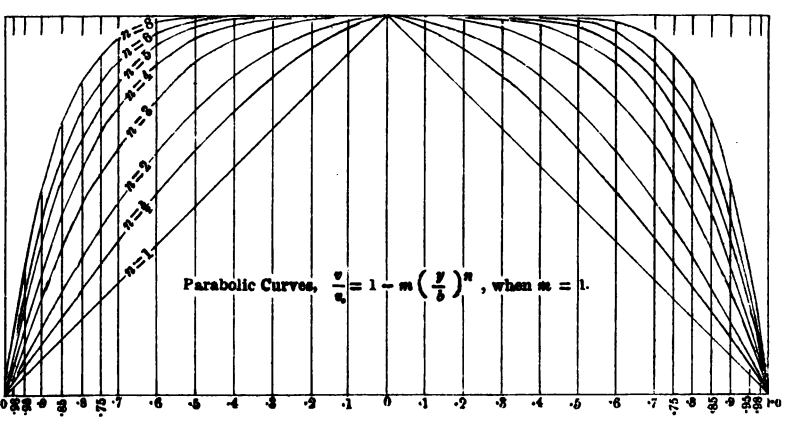
TRIAL TRANSVERSE CURVES.

[plotted from the ordinates shewn]

Length of Base-Transversal = 2b, from $y = -b$ to $y = +b$.
Abscisses (y) are reckoned of same sign as b, so that $\frac{y}{b}$ is always +.
Ordinates (v) are on such a scale that a_0, b are of equal lengths.


Catenary
Error-Curve
Logarithmic Curve
Catenary, $\frac{v}{a_0} = m.\left\{2 - \frac{1}{2}\left(\varepsilon^{\frac{y}{b}} + \varepsilon^{-\frac{y}{b}}\right)\right\}$, when $m = 1$.
Error-Curve, $\frac{v}{a_0} = m.\varepsilon^{-\left(\frac{y}{b}\right)^2}$, when $m = 1$.
Logarithmic Curve, $\frac{v}{a_0} = m.\varepsilon^{-\frac{y}{b}}$, when $m = 1$.





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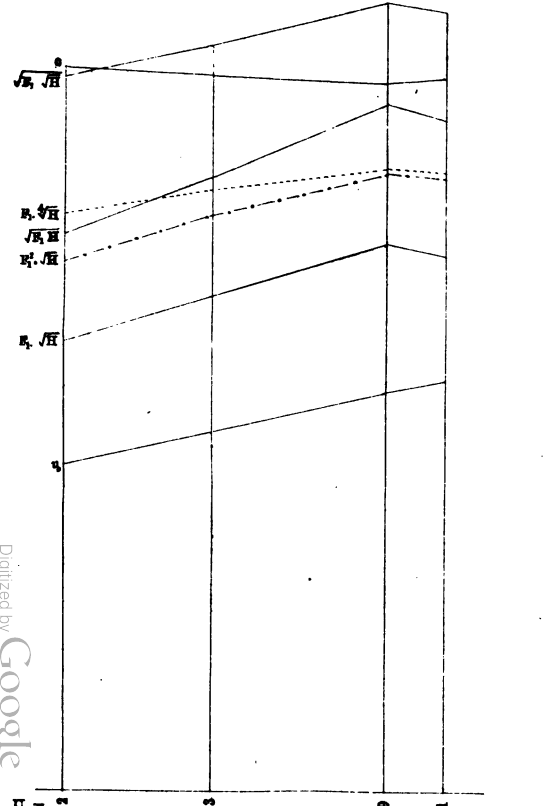
MEAN VELOCITY PAST CENTRAL VERTICAL—TRIAL CURVES.

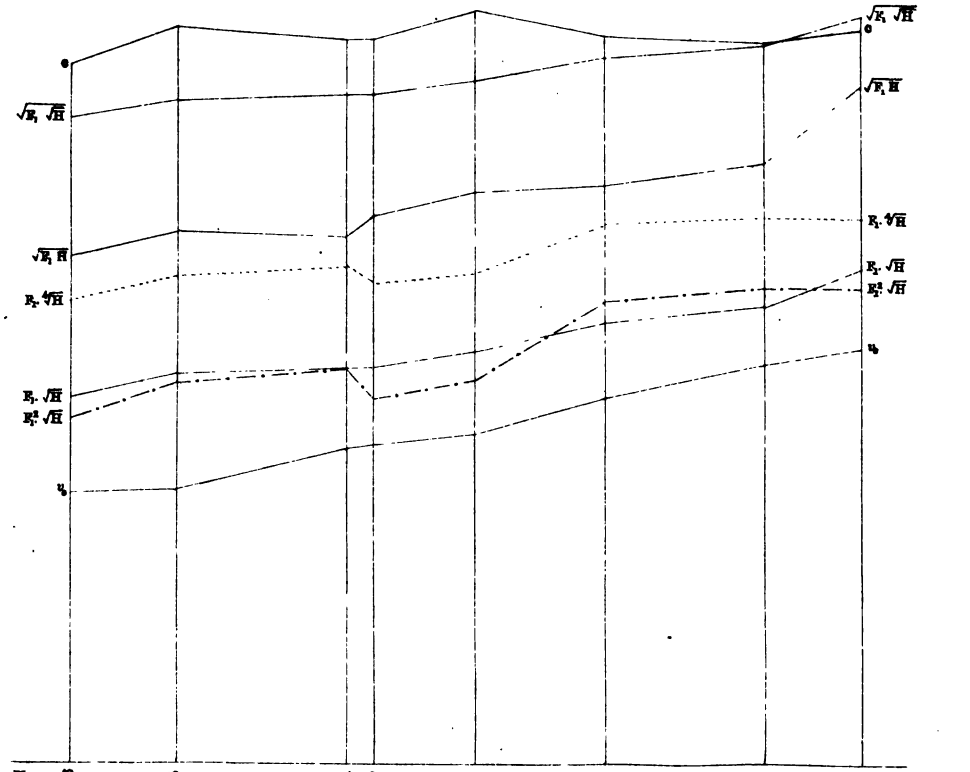
PLATE XLIII.

SOLANI LEFT AQUEDUCT



U =	3·83	3·63	3·99	4·11 ft. per sec.
Number of Sets	4	8	21	22
Serial No.	4 – 4	8 – 12	21 – 20	22 – 22

SOLANI EMBANKMENT MAIN SITE



U =	2·63	2·85	3·21	3·26	3·47	3·74	4·07	4·27 ft. per sec.
Number of Sets	16	7	16	6	16	12	10	16
Serial No.	1 – 16	1 – 7	1 – 16	1 – 6	1 – 16	1 – 12	1 – 10	1 – 16

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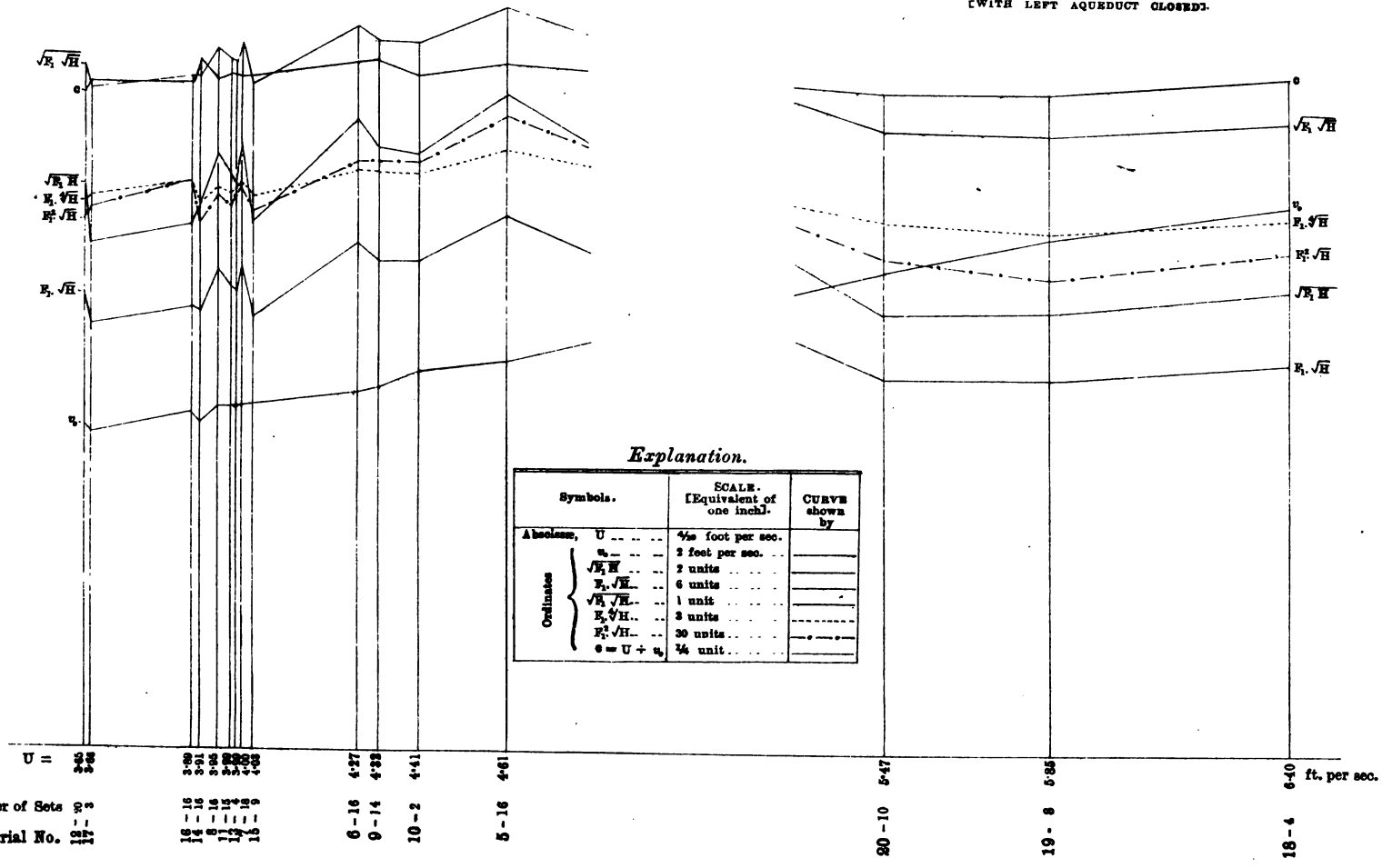
SOLANI RIGHT AQUEDUCT



Explanation.

Symbols.		SCALE. [Equivalent of one inch].	CURVE shown by
Abscissæ,	U	4/10 foot per sec.	
Ordinates	u_0	2 feet per sec.	
	$\sqrt{F_1 H}$	2 units	
	$F_1 \sqrt{H}$	6 units	
	$\sqrt{F_1 \sqrt{H}}$	1 unit	
	$F_1 \sqrt[3]{H}$	3 units	
	$F_1^2 \sqrt{H}$	30 units	
	$\theta = U \div u_0$	1/6 unit	

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CENTRAL AND MEAN SURFACE VELOCITY-VARIATION.

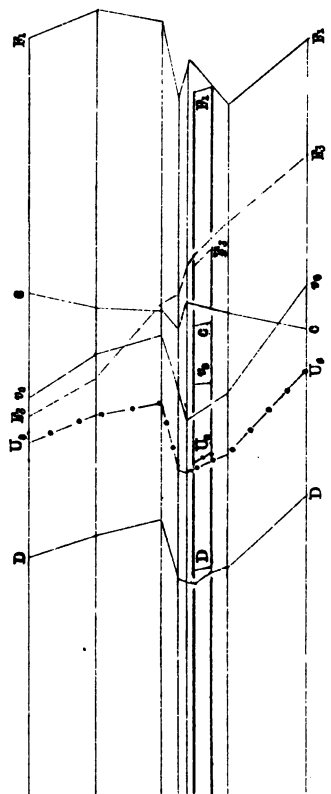
PLATE XLIV.

SOLANI AQUEDUCT SITES

Solâni Right Aqueduct Ordinates, thin lines. Solâni Left Aqueduct Ordinates, thick lines.

Explanation of symbols.

Symbol.		QUANTITY.	SCALE (Equivalent of one inch).	CURVE shown by
	R	Hydraulic Mean Depth, (Abscisse),	1 foot, ...	
Ordinates	D	Surface-Discharge, ...	100 sq. ft. per sec., ..	
	U_0	Mean Surface-Velocity, ...	1 ft. per sec., ...	—•—•—•—
	v_0	Central Surface-Velocity, ...	1 ft. per sec., ...	
	$\frac{v_0}{U_0}$	Ratio $U_0 \div v_0$, ...	$\frac{1}{20}$ units, ...	
	F_1	Fall in upper Sub-Reach (5 miles),	1 foot, ...	
	F_2	Fall in lower Sub-Reach (4½ miles),	1 foot, ...	



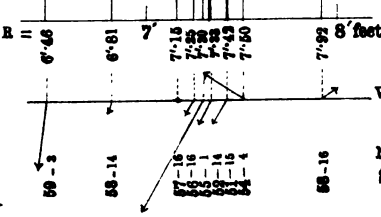
The Left Aqueduct ordinates (thick lines) are broken for clearness sake where crossed by the Right Aqueduct Curves.

WIND-SYMBOLS.

Scale, 20 feet per sec. to an inch.

Direction, as in Diagram.

Light Winds shown by a thick (•) dot.



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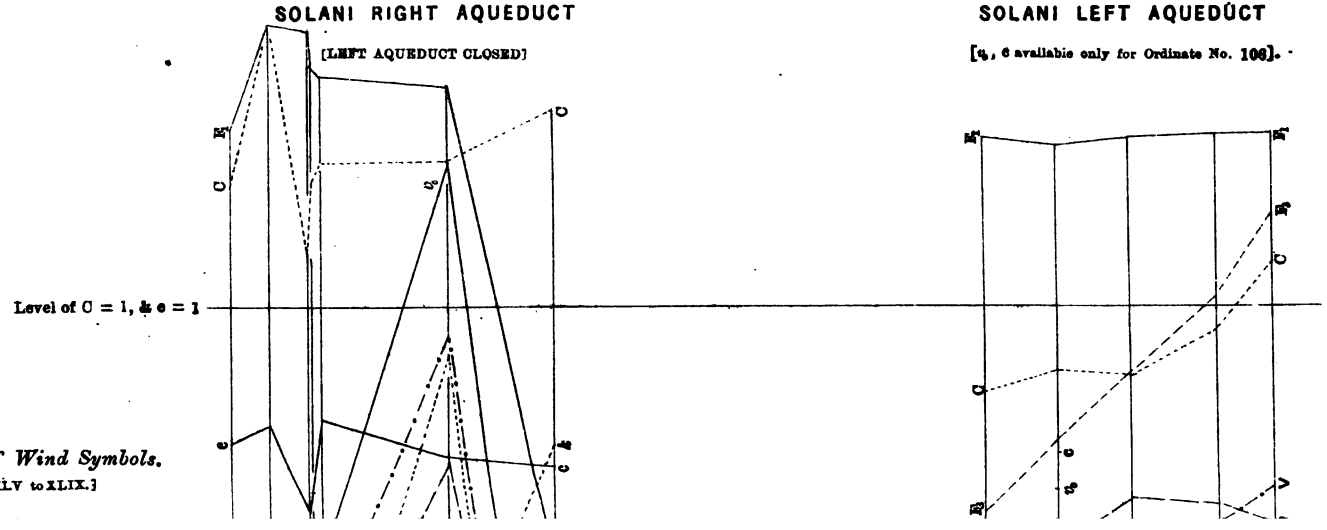
CENTRAL SURFACE AND MEAN VELOCITY-VARIATION.

Explanation of symbols, Plates XLV to XLIX.

Symbols		QUANTITY		SCALE Equivalent of one inch	CURVE shown by
	R	Hydr. Mean Depth, (Abscisse),	Pl. XLV. to XLVIII Pl. XLIX	1 foot ⅛ foot	
Ordinates	D	Cubic Discharge,	Pl. XLV to XLVIII Pl. XLIX	1000 cubic feet per sec. 200 cubic feet per sec.	———
	V	Mean (Sectional) Velocity,		1 foot per sec.	—·—·—·—
	v_1	Central Surface Velocity,		1 foot per sec.	———
	w	Value of 100. $\sqrt{RS}$,		1 foot per sec.	— — — —
	s	Local Surface-Slope,		·0001 units.	- - - - - -
	C	Ratio V ÷ w,		⅛ unit	·····
	e	Ratio V ÷ v_1,		⅛ unit	———
	h_1	Fall in upper Sub-Reach,		2 feet for Kambera Site; Plates XLVIII, XLIX.	———
	h_2	Fall in Middle Sub-Reach, (only in Plate XLVII),			- - - - -
	h_3	Fall in Lower Sub-Reach,		1 foot for all other Sites,	— — — —
	h	Average Height of Obstruction at Tail of Reach,			·····-
	Q	Withdrawal by Distributaries,		200 cubic feet per sec.	———
	σ	Silt Density, (only for Beira Site, Plate XLVIII),		500 gr. per cubic foot	·-·-·-·-·-

[Some of the ordinates are broken to prevent confusion in the drawing: a break in a curve indicates that its ordinate is unknown].



Explanation of Wind Symbols.
[Plates XLV to XLIX.]

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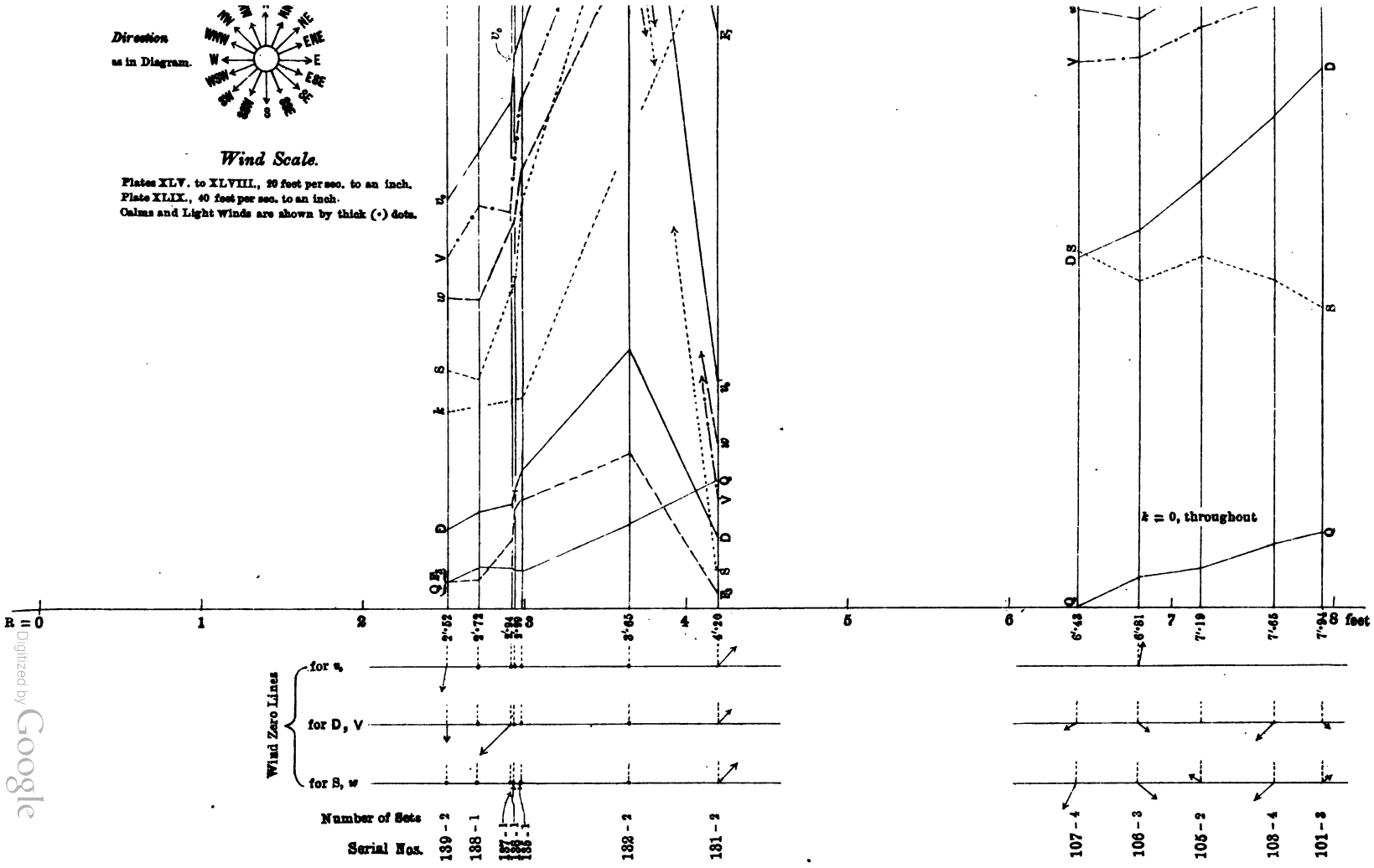

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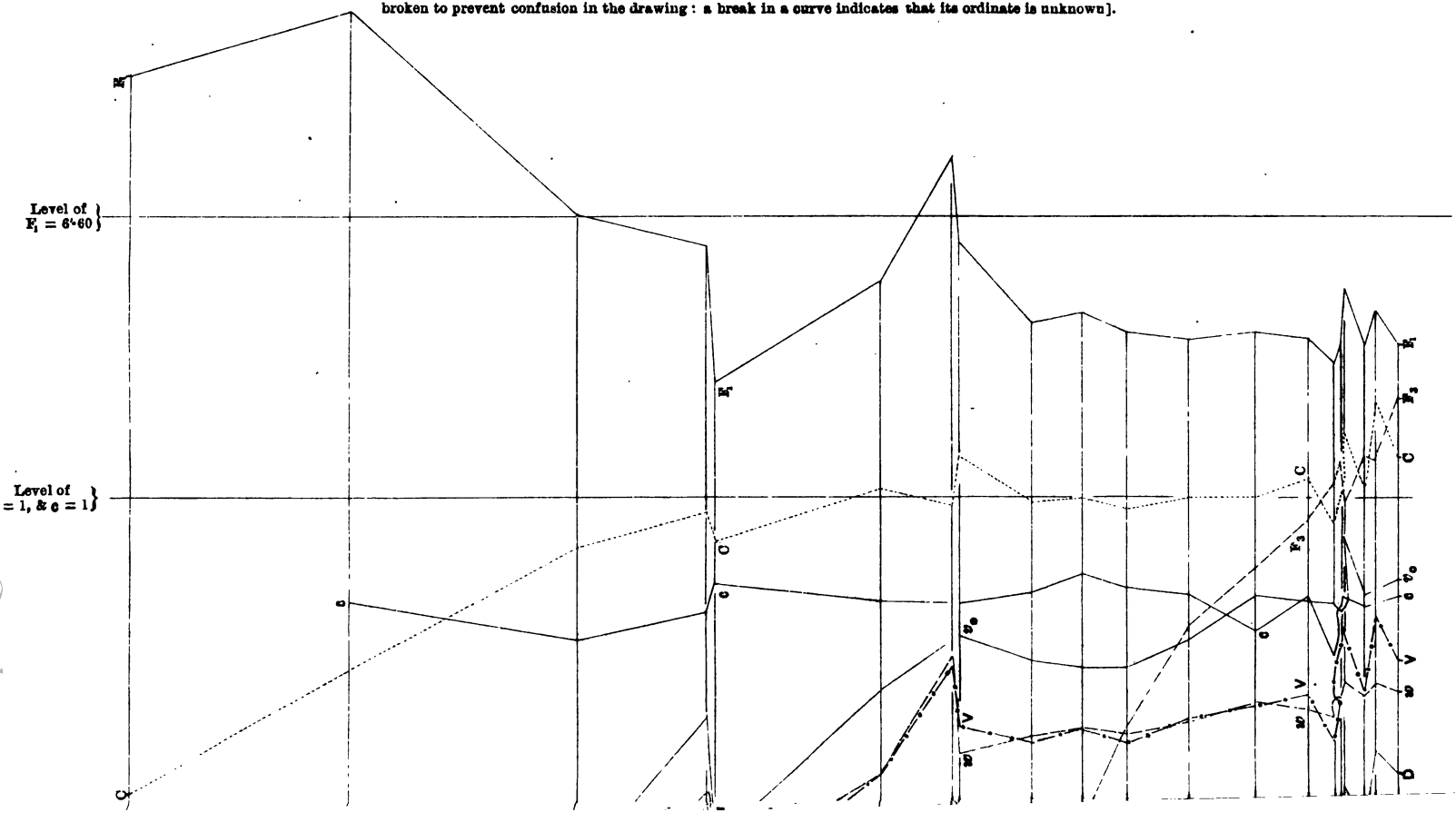
CENTRAL SURFACE AND MEAN VELOCITY-VARIATION.

SOLANI RIGHT AQUEDUCT

For explanation of symbols, scales, &c., see Plate XLV.

[*N.B.* The curves are formed by connecting the points plotted on the ordinates; the connexions are usually straight lines, but are drawn as freehand curves where necessary for clearness' sake. Some of the ordinates are broken to prevent confusion in the drawing: a break in a curve indicates that its ordinate is unknown].



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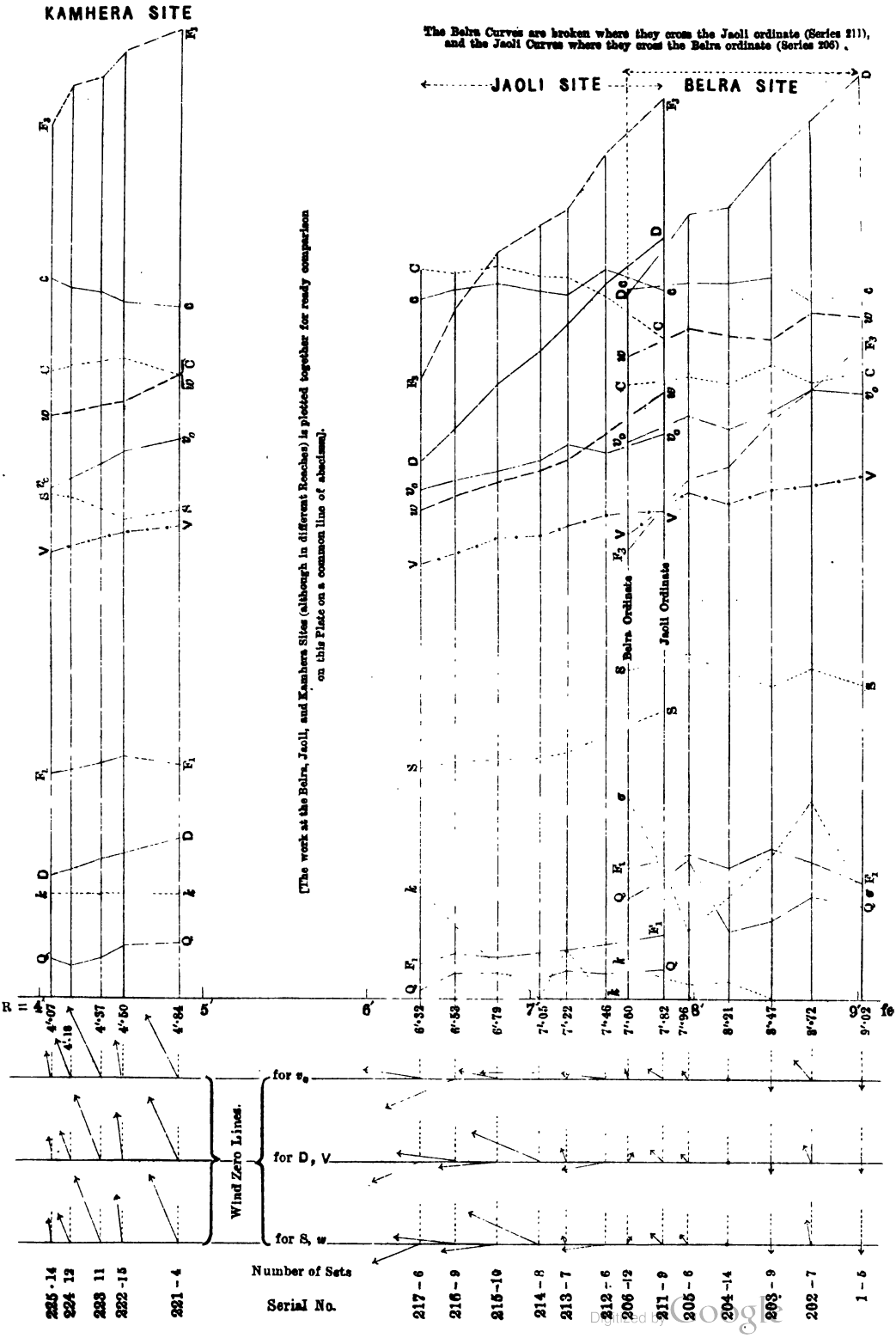
CENTRAL SURFACE AND MEAN VELOCITY-VARIATION.

For explanation of symbols, scales, &c., see Plate XLV.



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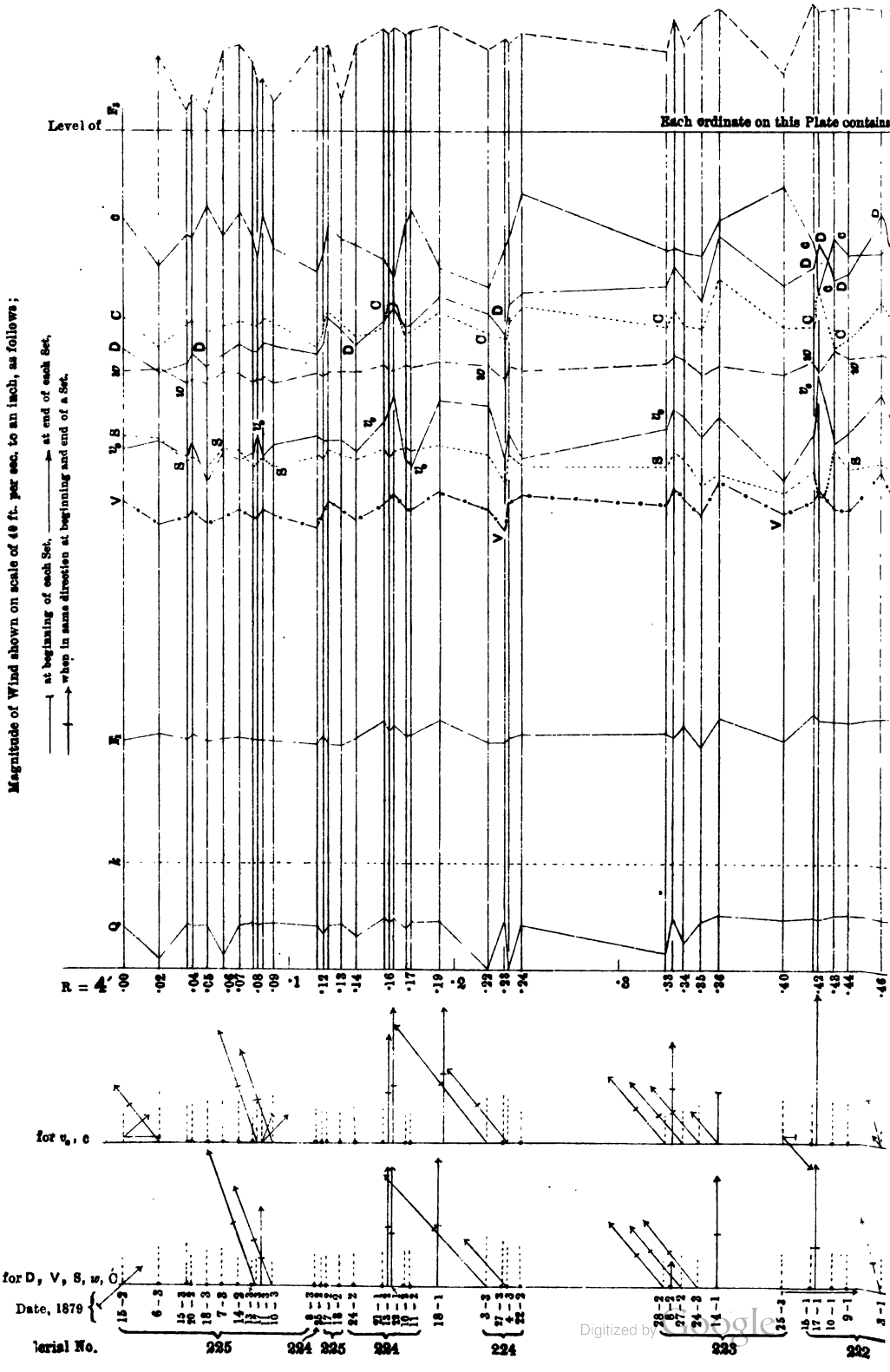
For explanation of symbols, se

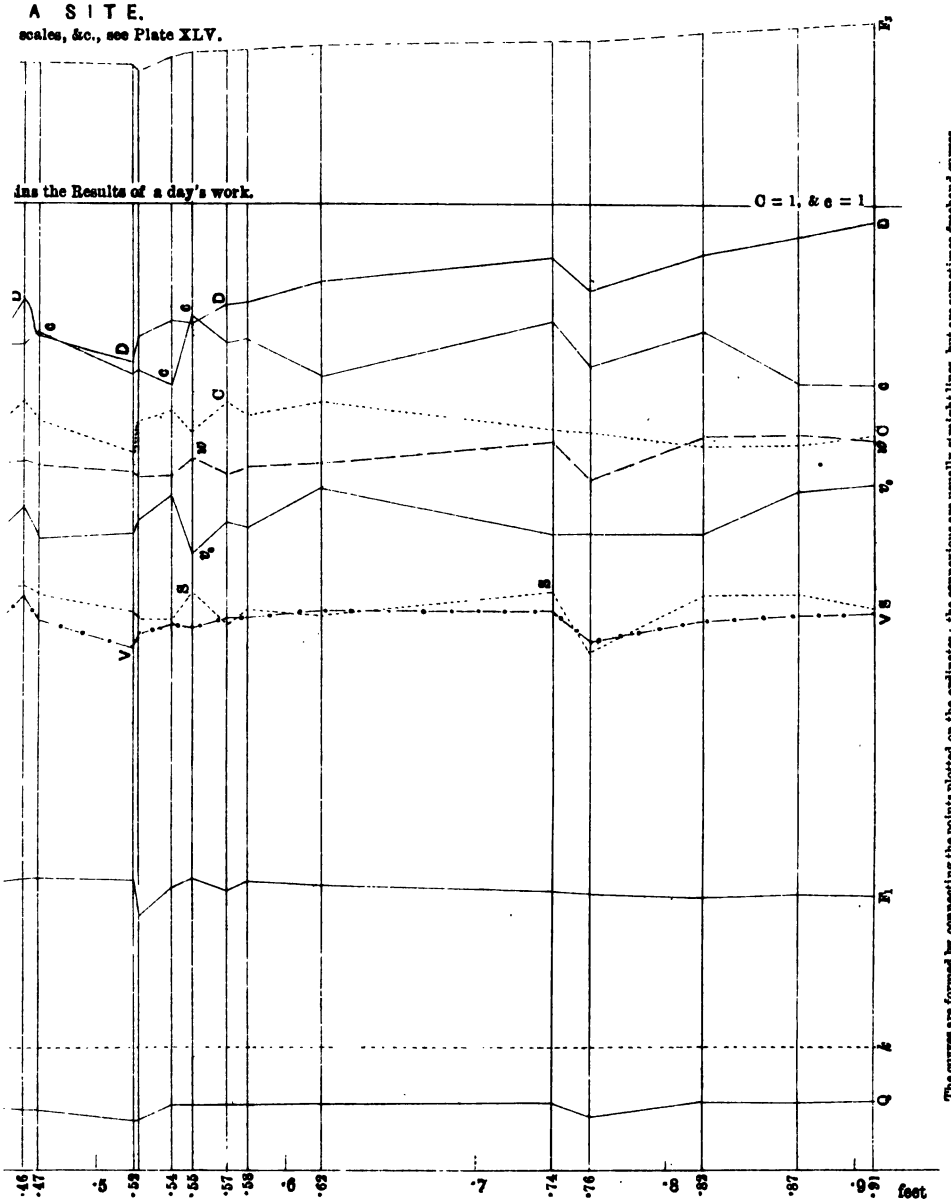


EAN VELOCITY-VARIATION.

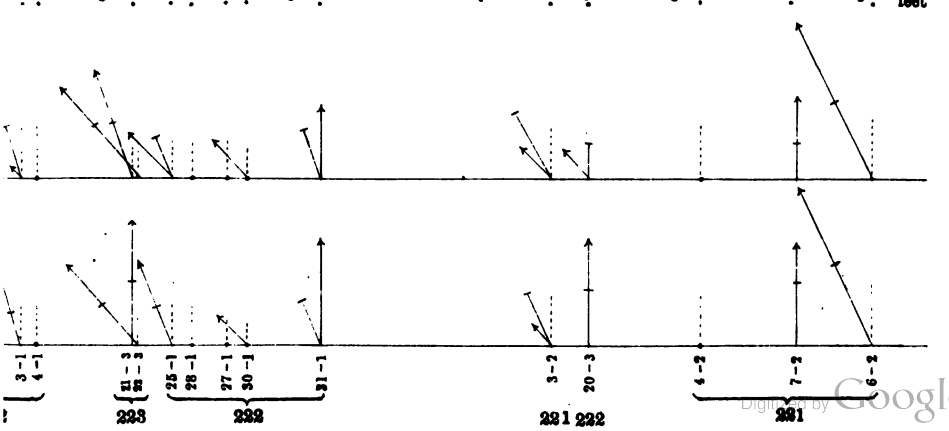
A SITE.

scales, &c., see Plate XLV.

dins the Results of a day's work.



The curves are formed by connecting the points plotted on the ordinates; the connexions are usually straight lines, but are sometimes freehand curves where necessary for clearness' sake. Some of the ordinates are broken to prevent confusion in the drawing.



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TRANSVERSE SILT VELOCITY-CURVES.

Scales, { *for Cross-Section, and for Abscisses, and for h, H, R, b, 25 feet to an inch.*
for Velocities (u), 2·5 feet per second to an inch.
for Silt-Densities (σ), 100 grains per cub. ft. to an inch in Fig. 1; 250 grains per cub. ft. to an inch in Fig. 2.
for Silt-Velocities, (s), 250 grains per sec. to an inch in Fig. 1; 1000 grains per sec. to an inch in Fig. 2.

References, { Rod-Velocity Curve, and Mean (Sectional) Velocity Line.
Silt-Density Curve, and Mean Silt-Density Line.
Silt-Velocity Curve, and Mean Silt Velocity Line.

FIG. 1.

SOLANI RIGHT AQUEDUCT

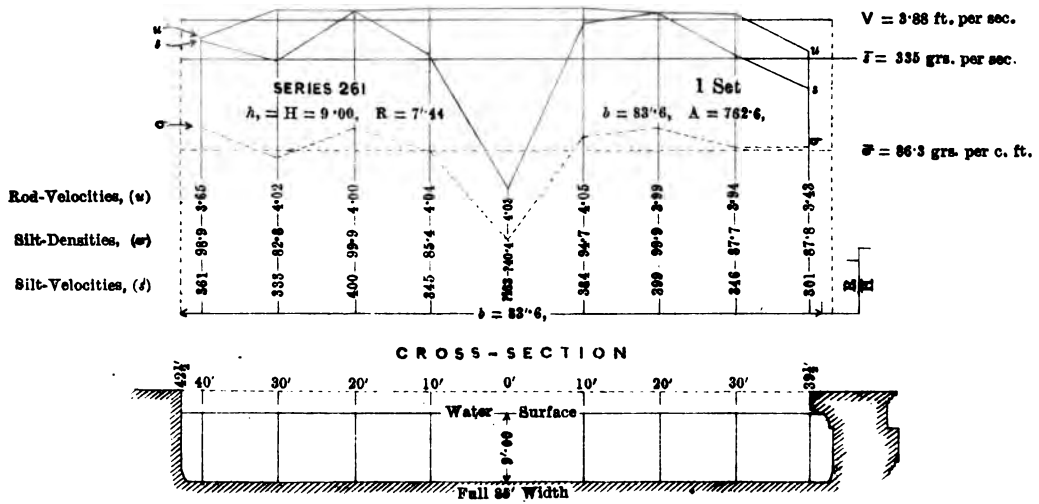
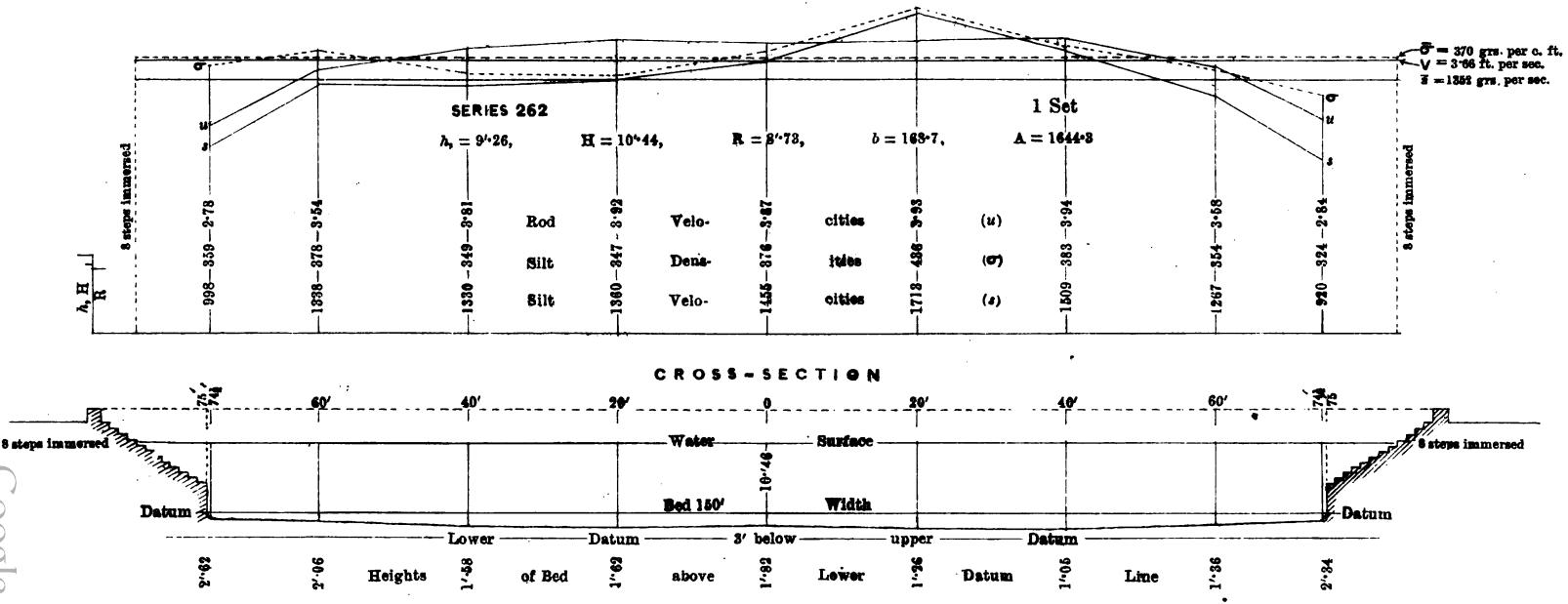


FIG. 2.

SOLANI EMBANKMENT MAIN SITE


σ = 370 grs. per c. ft.
V = 3·66 ft. per sec.
Ī = 1352 grs. per sec.
SERIES 262
1 Set
h, = 9·26, H = 10·44, R = 8·73, b = 163·7, A = 1644·3
8 steps immersed
8 steps immersed
h, H R
998 — 359 — 2·78
1338 — 378 — 3·54
1330 — 349 — 3·81
1360 — 347 — 3·92
1455 — 376 — 3·87
1718 — 486 — 3·93
1509 — 383 — 3·94
1267 — 354 — 3·58
920 — 324 — 2·84
Rod Velo- cities (u)
Silt Dens- ities (σ)
Silt Velo- cities (s)
CROSS-SECTION
75 74
60′ 40′ 20′ 0 20′ 40′ 60′
74 75
8 steps immersed
8 steps immersed
Water Surface
10·46
Datum
Bed 150′ Width
Datum
Lower Datum 3′ below upper Datum
2·62 2·06 Heights 1·58 of Bed 1·62 above 1·62 Lower 1·36 Datum 1·05 Line 1·36 2·84

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CURRENT-M

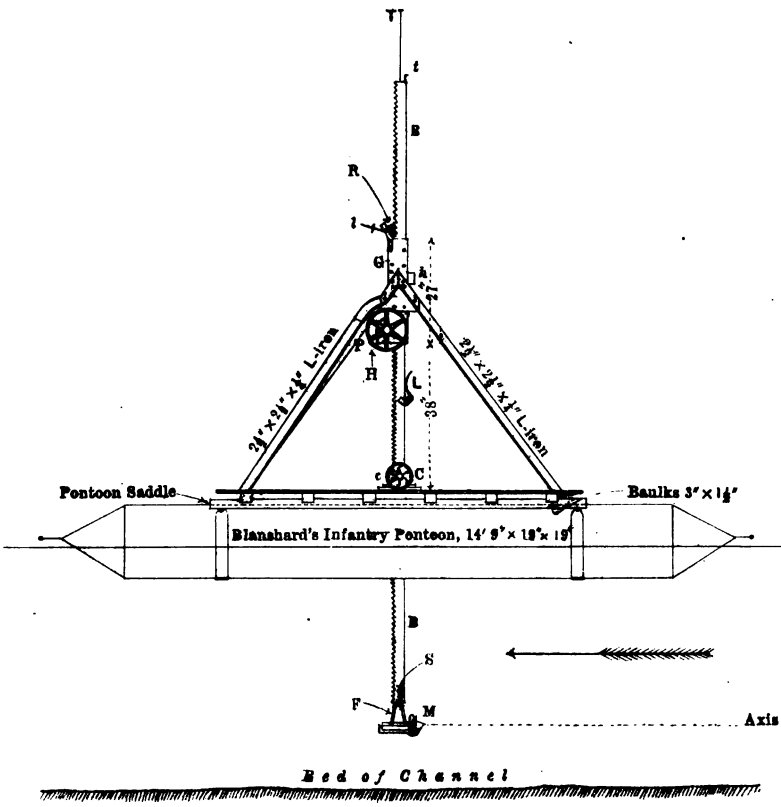
[ON PONT

Scale for Fig. 1 *to* 4,

Scale for Fig. 5 *to* 8,

FIG. 1.

Side Elevation, ¼th Size



Front E

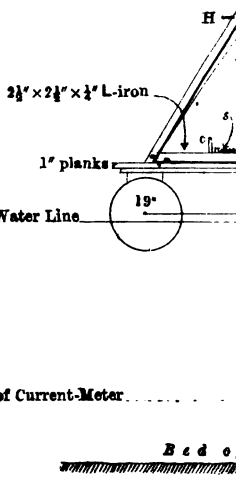
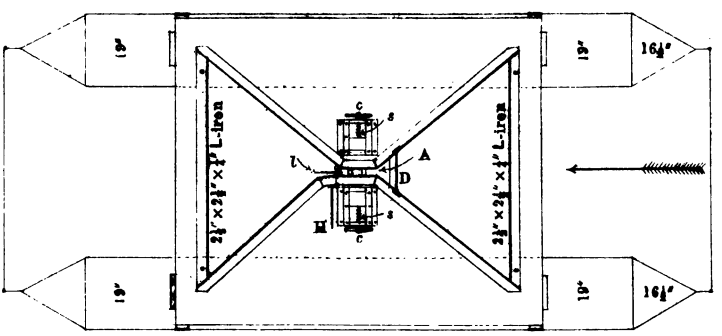
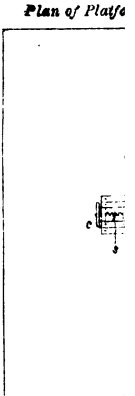


FIG. 3.

General Plan, ¼th Size,



Plan of Platfo



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T-METER LIFT.

ONTOON RAFT].

o 4, 50 *inches to an inch.*

o 8, 12 *inches, to an inch.*

FIG. 2.

ont Elevation ¼th Size.

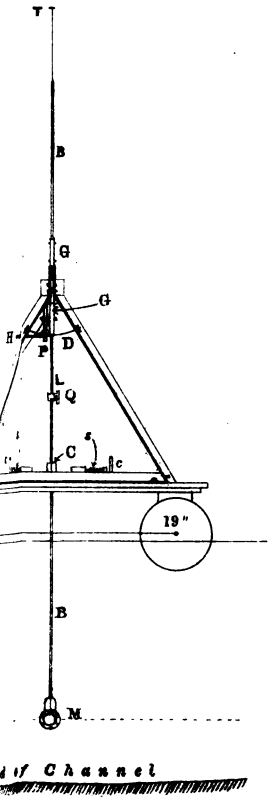
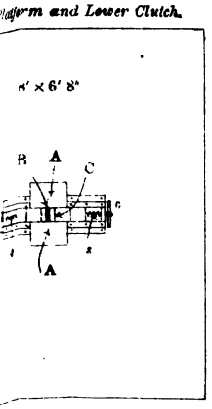


FIG. 4.

latform and Lower Clutch.



DETAILS.

G, Guide-Piece of Lift-Bar, (27" × 5" × 1½" outside, 27" × 3" × ¾" inside).
f, Front-Piece of above, (27" × 1" × ¾"), removable for changing Lift-Bar.
h, Handle of above.
D, Curved Distance-Piece between front Legs of Lift.
B, Lift-Bar (3" × ¾") section, grooved in front, and racked behind.
T, T-Head of Lift-Bar.
r, Toothed Rack of Lift-Bar.
R, Safety Ratchet for ditto.
l, Lever of Ratchet.
P, Crank-wheel of Pinion working the Lift-Bar.
H, Handle of ..... ditto.
w, Gearing Wire (¼" thick) contained within the groove of Lift-Bar.
t, T-Head of Gearing Wire.
o, Gearing Holes in the Gearing Wire for inserting nose of Gearing Lever.
s, Hole in Gearing Wire for insertion of Union-Link of Current-Meter.
b, Bridges across Groove of Lift-Bar, to support Gearing Wire.
L, Gearing Lever.
Q, Screw Handle of above (for fixing Gearing Lever on Lift-Bar).
S, Socket for insertion of Current-Meter Foot.
F, Foot for attachment of Current-Meter.
M, Current-Metre (Moore's pattern is shown).
A, Opening in Platform (17" × 8") for passage of Current-Meter.
C, Cheeks of Lower Clutch.
s, Pair of Screws working Clutch.
c, Pair of Crank-wheels working Clutch.

Enlarged Views

of Lift-Bar (B), Gearing Wire (*w*), and Gearing Lever (L).

Cross-Sections.

FIG. 6.

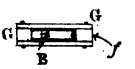


FIG. 8.

FIG. 5 *Side Elevation ¼th Size.*

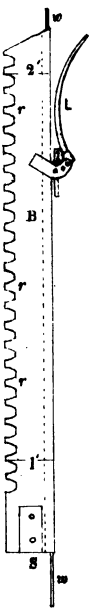


FIG. 7. *Front Elevation ¼th Size.*

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THEORY OF ROD-MOTION.

Vertex (A) is origin of co-ordinates. The parabola-axis Aa is the x-axis. Ll is the Rod in position; cC the Rod-velocity (u).
Positive ordinates (z) measured vertically downwards (from Aa). bB is the Surface-level.
$aA = V$, $bB = v_o$, $cC = u$, $pP = v$, $dD = v_l$; $bd = l$, $ab = Z$, $ac = h$, $ap = z$, $ad = Z'$.
$bd = Ll = Z' - Z = l$.

FIG. 1.

Parabola-axis (Aa) above surface-level (bB).

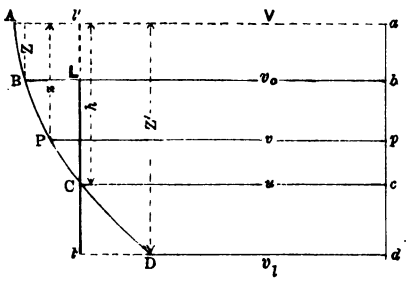


FIG. 2.

Parabola-axis (Aa) in the surface (bB).

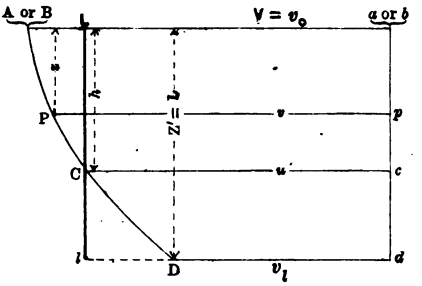


FIG. 3.

Parabola-axis (Aa) below surface-level (bB).
Rod-velocity (cC) < surface-velocity (bB).

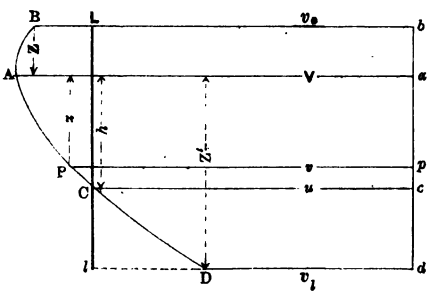


FIG. 4.

Parabola-axis (aA) below surface-level (bB).
Rod-velocity (cC) = surface-velocity (bB).

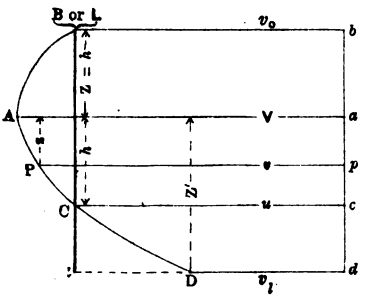
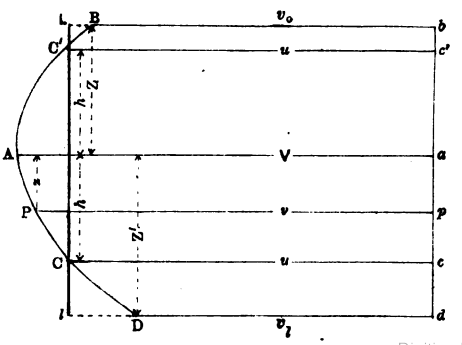


FIG. 5

Parabola-axis (Aa) below surface-level (bB).
Rod-velocity (cC or $c'C'$) > surface-velocity (bB).



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